2005 Monitoring of Algodones Dunes Sunflower
and
Psammophytic Vegetation
in the
Algodones Dunes, Imperial County, California

Bureau of Land Management
California State Office
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Contents

Preface

The author of this report is John Willoughby, State Botanist, Bureau of Land Management (BLM), California State Office. Dunes-wide monitoring that began in 2004 (Willoughby 2005b) was continued and intensified in 2005. The 2004 monitoring was an expansion and refinement of a pilot monitoring study conducted in 2003 in two of the seven management areas of the Dunes that support Peirson's milk-vetch and Algodones Dunes sunflower. The 2003 pilot study itself benefited from previous pilot sampling of Peirson's milk-vetch and Algodones Dunes sunflower in 2001 and 2002 that was conducted in conjunction with an abundance class monitoring study implemented by BLM between 1998 and 2002 (see Willoughby 2000, 2001, and 2004 for a description of the 1998-2002 monitoring study). The 2003 pilot sampling study is described in Willoughby (2005a); some results from that study are also included in this report. The 2005 monitoring results for Peirson's milk-vetch are provided in a separate report (Willoughby 2005c). Results for Algodones Dunes sunflower and for psammophytic vegetation are provided in this report.

The study was designed by John Willoughby in consultation with Chris Knauf of the El Centro Field Office, the BLM office responsible for management of the Algodones Dunes. Chris coordinated every aspect of monitoring implementation. The study would not have been possible without his extraordinary leadership. Joelle Viau was contracted by BLM to assist Chris and provided exemplary day-to-day oversight of the monitoring. Erin Dreyfuss and Daniel Steward, both of the El Centro Field Office, also provided very valuable assistance in coordinating and carrying out the study. Erin assisted in the daily oversight of the project, provided training to the monitors in plant identification, and substituted for monitors in walking transects as required. Daniel assisted primarily in the computer applications required by the study. Fran Evanisko of the BLM California State Office provided extremely valuable support in applying the ArcGIS Geographical Information System (ESRI 2004) to the planning of the study and to the analysis and presentation of the data collected.

The study itself was carried out by 36 employees of the Environmental Careers Organization of Boston, Massachusetts, working in teams of 3. The following ECO personnel walked the 3,098 kilometers of transects, took and recorded the data required for the study, and provided data input and quality control: Kellie Burtch, Ursula Carliss, Michael Carlson, James Christopolous, Tami Clayton, Cato Cook, Saana Deichsel, Brent Eastly, Robert Eckert, Jesse Erickson, Laurie Gilligan, Jamie Granger, Dawn Graydon, Emily Howe, Danielle Jarois, Karen Kavenaugh, Aaron Keller, Matt Lachance, Steve Lee, Michelle Maley, Holly Mercier, Brenda Morton, Carlos Navarro Jr., Shannon Page, Lila Prichard, Gina Radieve, Matt Reed, Darwin Richardson, Dana Robison, Diane Rombalski, Dan Thomas, Andrew Trouette, Joe Veverka, Matt Villaneva, Carey Zinck, and Jordon Zylstra. The success of the study is a direct result of their dedication and hard work.

Executive Summary

In late winter and spring 2005, the Bureau of Land Management (BLM) implemented a monitoring program to estimate the density and population size of two special status species, Peirson's milk-vetch (*Astragalus magdalenae* var. *peirsonii*) and Algodones Dunes sunflower (*Helianthus niveus* ssp. *tephrodes*), and the canopy cover of the associated vegetation in the Algodones Dunes (also called Imperial Sand Dunes), located in southeastern Imperial County, California. Peirson's milk-vetch is a Federally-listed threatened species and a State-listed endangered species. Algodones Dunes sunflower is a State-listed endangered species. The 2005 monitoring results for Peirson's milk-vetch are provided in a separate report (Willoughby 2005c). Results for Algodones Dunes sunflower and for psammophytic (sand-loving) vegetation—the vegetation associated with both Peirson's milk-vetch and Algodones Dunes sunflower—are provided in this report.

The Imperial Sand Dunes Recreation Area Management Plan (ISDRAMP), approved by the BLM California State Director in 2005, established eight management areas. The objective of BLM's Monitoring/Study Plan, contained in the ISDRAMP, is to obtain density and population size estimates of the Algodones Dunes sunflower in each of the seven management areas in which it occurs. Dunes-wide monitoring for the species began in 2004, following pilot monitoring in the Wilderness and Gecko management areas in 2003.

A total of 510 belt transects, ranging in length from 2.35 to 7.75 kilometers, were positioned systematically with a random start within 16 sampling areas located within the seven management areas. Transects were 25m wide, and counts were recorded in 25m segments along each of the transects. Counts of Algodones Dunes sunflower were made of the number of plants in each of five categories: (1) nonflowering adult plants, (2) flowering plants, (3) total number of adult plants (this is the total of categories 1 and 2), (4) number of plants showing damage from off-highway vehicles (OHVs), and (5) number of plants showing damage from sources other than OHVs. The study plan originally called for counting the number of sunflower seedlings in 5m wide belt transects (the 5m wide belt was to be employed as in 2004 because the very high numbers of seedlings was expected to result in far too many plants to count in 25m wide belts). After about two weeks of sampling in 2005, it became clear that there were many more sunflower seedlings in 2005 than in 2004 and that if monitors continued to count seedlings they would be unable to finish all of the transects planned for 2005. In order to ensure completion of all transects, it was decided to cease counting sunflower seedlings. The seedling counts in the first two weeks of the monitoring do provide rough estimates of the number of seedlings in the Dunes as a whole and in those management areas where seedlings were counted.

The 2004-2005 growing season was very favorable for the germination of *Helianthus niveus* ssp. *tephrodes*. As many as 10 million seedlings germinated in response to rains beginning in October 2004, far more than the 1.7 million seedlings estimated in 2004. However, the estimated number of 325,122 adult sunflower plants in 2005 was not significantly different from the estimated 2004 number of 277,955 adults, likely because growing conditions in the 2003-2004 growing season were not favorable to the recruitment of adult plants into the population. It is likely that growing conditions have not been favorable for the recruitment of seedlings into the population since the 2000-2001 growing season. The large 2004-2005 seedling cohort may

result in greater numbers of adults in 2006, depending on how many plants of that cohort survive the hot summer months.

The canopy cover of HENIT in the Dunes was greater in 2005 than in 2004 in every management area of the Dunes, likely the result of increased stem and leaf growth in 2005 in response to 2004-2005 growing season rainfall that was greater and better distributed than raintfall in the 2003-2004 growing season.

An estimated 0.6% of the total number of estimated adult HENIT plants showed signs of damage from OHVs in 2005, ranging from a low of 0.0% in the Wilderness Management Area to a high of 13.4% in the Buttercup Management Area. The relatively high percentage of plants damaged in the Buttercup Management Area is likely the result of high concentrated OHV use in that management area, which is considerably smaller than the other six management areas and located near a major OHV camping and staging area. The Glamis and Gecko management areas, respectively, experienced the next highest percentage of plants with OHV damage (1.4% and 0.7%, respectively).

An estimated 4.1% of the total number of estimated adult HENIT plants showed signs of damage from sources other than OHVs, principally from sunflower rust. Damage ranged from a low of 1.1% in the Mammoth Wash Management Area to 7.3% in the Glamis Management Area. The rust damage is not expected to be lethal to most of the adult HENIT plants infected.

Total perennial psammophytic vegetation canopy cover was an estimated 2.3% in total cover over the areas of the dunes that were sampled. Total cover was lowest in the Buttercup Management Area and highest in the Wilderness Management Area. There appeared to be both north-south and west-east gradients in total cover, with cover higher in the northern and western parts of the Dunes than in the southern and eastern parts of the Dunes.

Dunes-wide, total perennial plant cover was significantly greater in 2005 than in 2004, consistent with what would be expected given the much greater and better distributed 2004-2005 growing season precipitation. Except for the Buttercup Management Area, this same trend was observed in every management area. *Eriogonum deserticola* had the highest cover of any perennial species in the Dunes as a whole, followed by the perennials *Helianthus niveus* var. *tephrodes* and *Croton wigginsii*. The growing season 2004-2005 was also favorable to the growth of the robust annual *Dicoria canescens*, which had canopy cover nearly equal to *Eriogonum deserticola* in 2005, but essentially no cover in 2004.

Introduction

In late winter and spring 2005, the Bureau of Land Management (BLM) implemented a monitoring program to estimate the density and population size of Peirson's milk-vetch (*Astragalus magdalenae* var. *peirsonii*, hereafter referred to as ASMAP) and Algodones Dunes sunflower (*Helianthus niveus* ssp. *tephrodes*, hereafter referred to as HENIT) in the Algodones Dunes (also called Imperial Sand Dunes), located in southeastern Imperial County, California. ASMAP is a Federally-listed threatened species and a State-listed endangered species. HENIT is a State-listed endangered species. The monitoring was designed to also provide estimates of the canopy cover of the vegetation associated with these two plant species. This vegetation has been termed psammophytic (sand-loving) by Thorne (1976 and 1982). Though the survey began in late winter 2005, it will be referred to simply as the spring 2005 survey hereafter. The 2005 monitoring results for Peirson's milk-vetch are provided in a separate report (Willoughby 2005c). Results for the HENIT and psammophytic vegetation monitoring are provided in this report.

The Imperial Sand Dunes Recreation Area Management Plan (ISDRAMP), approved by the BLM California State Director in 2005, established eight management areas (Map 1). The objective of BLM's Monitoring/Study Plan, contained in the ISDRAMP, is to obtain density and population size estimates of HENIT in each of the seven management areas in which it occurs. Dunes-wide monitoring for HENIT began in 2004, following pilot monitoring in the Wilderness and Gecko management areas in 2003. The 2003 pilot study itself benefited from previous pilot sampling of Algodones Dunes sunflower in 2001 and 2002 that was conducted in conjunction with an abundance class monitoring study implemented by BLM between 1998 and 2002 (see Willoughby 2000, 2001, and 2004 for a description of the 1998-2002 monitoring study). The results of the 2004 monitoring were reported in Willoughby (2005b); results from the 2003 pilot monitoring were reported in Willoughby (2005a). The 2005 results are reported here.

Methods

Two or more rectangular sampling areas were delineated in each of the seven management areas of the Algodones Dunes (Map 2), for a total of 16 sampling areas. Sampling area boundaries were placed so that the major part of the habitat of ASMAP was encompassed within the sampling areas.[1] Rectangles were used to facilitate the systematic random placement of belt transects. This resulted in two sampling areas in each of the management areas except for the Adaptive Management Area (AMA), in which four sampling areas were established. Each of the sampling areas was given a unique number, as shown on Map 2.[2]

[1] Because of its status as a federally listed species, the sampling areas were focused on Peirson's milk-vetch and were positioned to incorporate as much of that species' habitat as practical. Because Algodones Dunes sunflower occupies the same or very similar habitat as Peirson's milk-vetch, the sampling areas delineated for Peirson's milk-vetch are also optimal for Algodones Dunes sunflower.

[2] Based on the 2004 monitoring data, four additional sampling areas were added in 2005. The Mammoth Wash, Wilderness, and Ogilby management areas each had a single sampling area in 2004. These single 2004 sampling areas were each divided into two sampling areas for the 2005 sampling. The Adaptive Management Area (AMA)

Each of the sampling areas consisted of a rectangle with its long sides oriented approximately northwest to southeast (the Buttercup 11 sampling area approximates a square). The shorter top side of each sampling area rectangle functioned as a baseline from which 25m wide belt transects were run perpendicular to the baseline and therefore parallel to each of the long sides of the sampling area rectangle. The starting points for each of the transects established in 2004 was determined using systematic sampling with a random start (see Willoughby 2005b for more information on this process). A total of 135 transects were established in 2004 (Table 1 shows the number of 2004 transects in each of the sampling areas). In 2005 all of the transects established in 2004 were reread and additional transects were added to improve the precision of the 2005 estimates. These additional transects were added again by using systematic sampling with a random start, with the caveat that no new transect could be within 25m of a transect established in 2004. Table 1 shows the number of transects placed in each of the sampling areas, the lengths of each transect, and the total area encompassed by each sampling area.

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had three sampling areas in 2004. One of these AMA sampling areas was divided in two for the 2005 monitoring. Sampling areas 3, 4, 5, 6, 7, 8, 11, and 12 on Map 2 are the same sampling areas monitored in 2004. Sampling areas 13, 14, 15, 16, 17, 18, 19, and 20 were newly created for the 2005 sampling, as described above. To avoid confusion, 2004 sampling areas that were divided in 2005 were given different numbers. Thus, no 2005 sampling areas were given the numbers 1, 2, 9, or 10. The total habitat area sampled in 2005 was the same as in 2004; the only difference in 2005 was how that area was divided for purposes of sampling. Density and population estimates for each of the management areas are directly comparable between 2004 and 2005.

Table 1. Sampling areas for the 2005 special status plant monitoring in the Algodones Dunes.

Management Area	Sampling Area Number	Number of 2004 Transects *	Number of 2005 Transects **	Transect Length (km)	Area Within Sampling Area (ha)
Mammoth Wash	13	15	30	4.45	668.22
	14	15	30	4.45	668.22
Wilderness	15	15	25	7.08	1,246.46
	16	15	25	7.08	1,246.22
Gecko	3	9	25	6.54	1,891.70
	4	9	25	6.54	1,888.60
Glamis	5	9	25	6.24	1,815.29
	6	9	25	6.24	1,817.87
AMA	7	5	38	6.15	1,362.91
	8	5	33	5.38	1,176.88
	17	5	42	6.95	1,527.49
	18	4	42	6.95	1,527.49
Ogilby	19	9	43	7.73	1,698.49
	20	9	43	7.73	1,698.49
Buttercup	11	16	29	2.35	463.63
	12	16	30	3.58	509.23
Total		165	510		21,207.19

* The Mammoth Wash and Wilderness management areas each had a single sampling area sampled by 15 transects in 2004. In 2005 each of the 2004 sampling areas was divided in half by a line running perpendicular to the direction of the transects. Thus, each of the new sampling areas within each management area included the same number of transects as 2004, but the length of the transects in each of the 2005 sampling areas was half the length of the 2004 transects. This is the reason that this column totals 165 transects instead of the 135 transects that were actually read in 2004.

** The number of 2005 transects includes the 2004 transects plus the transects added in 2005.

The sampling objective articulated in the ISDRAMP Monitoring/Study Plan is directed toward ASMAP: to achieve estimates of ASMAP that are within 30% of the true total population size at the 95% confidence level for each of the management areas. The number of transects to be placed in each of the sampling areas in 2005 was determined based on the ASMAP sample variance obtained for each of the management areas in 2004. Though the monitoring is not designed to obtain estimates with these precision levels for HENIT, the hope is that monitoring that meets the sampling objective for ASMAP will also result in similar levels of precision for HENIT.

Each transect was a 25m wide belt. The beginning and ending points of each transect were entered into Hewlett Packard iPAQ Personal Data Assistants running ArcPad Mobile GIS (ESRI

2004), along with points corresponding to each 25m segment along each transect. GPS units attached to the iPAQs were then used to navigate between each of the 25m points from the beginning to the end of each transect. Counts were made of the number of HENIT individuals in each of 5 categories described below within each of the 25m segments. This enabled the creation of maps showing the cells along each of the transects that were occupied by these species and the number of plants found in each of the cells. Separate counts were made for the following categories: (1) adult nonflowering plants, (2) flowering plants, (3) total number of adult plants (this is the total of categories 1 and 2), (4) number of plants showing damage from OHVs, and (5) number of plants showing damage from sources other than OHVs. The study plan originally called for counting the number of sunflower seedlings in 5m wide belt transects (the 5m wide belt was to be employed as in 2004 because the very high numbers of seedlings was expected to result in far too many plants to count in 25m wide belts). After about two weeks of sampling in 2005, it became clear that there were many more sunflower seedlings in 2005 than in 2004 and that if monitors continued to count seedlings they would be unable to finish all of the transects planned for 2005. In order to ensure completion of all transects, it was decided to cease counting sunflower seedlings. The seedling counts in the first two weeks of the monitoring do provide rough estimates of the number of seedlings in the Dunes as a whole and in those management areas where seedlings were counted.

Although individual HENIT seedling plants can be readily distinguished and counted, the same is not true for adult plants, whether flowering or not. Because HENIT apparently spreads by branches that lie down in the sand and take root, it is difficult to actually determine genetic individuals except through tedious excavation that is too time consuming and too damaging to the plants for this monitoring effort. Therefore, the following rule was used to determine "individual" adult HENIT plants:

- If HENIT stems were greater than 1 m apart they were considered to be two different plants.
- If HENIT stems were less than 1 m apart they were considered to be one individual plant.

Density and population estimates were made based on the transect values. Estimates of densities and population totals were made separately for each sampling area, treating the systematic random samples as if they were simple random samples (this is a common practice in natural resource sampling—see, for example, Schreuder et al. 2004). Sampling area estimates were consolidated into a management area estimate by treating each sampling area as a separate stratum and using formulas for stratified random sampling. The survey module in the statistical program Stata Release 9 (StataCorp 2005) automates these formulas and was used to calculate the estimates and confidence intervals reported here. Because sampling was without replacement, the finite population correction factor was used in the calculation of the confidence intervals. Because transects were of different lengths, a ratio estimator of the mean number of plants per transect divided by the mean area per transect was used to estimate density and population size as recommended by Stehman and Salzer (2000) to avoid potential problems in estimating these parameters for the Dunes and a whole and for those management areas (AMA and Buttercup) with belt transects of unequal area. [3]

[3] Ratio estimation proved to be an unnecessary precaution with this dataset. The data were analyzed using both the svy: ratio and svy: total commands in Stata release 9 (the latter command ignores the difference in belt area) and the

Precipitation data were obtained from two remote area weather stations (RAWS), one located in the northern half of the dunes at the Cahuilla Ranger Station near State Highway 78 on the western edge of the dunes and the other at Buttercup in the southern part of the dunes south of Interstate 8. These data were compared to long-term average precipitation obtained from the Western Regional Climate Center for weather stations in the vicinity of the Dunes. The locations of these stations are shown in Willoughby (2004).

Psammophytic vegetation data was collected by means of the line-intercept method (Canfield 1941). Line-intercept transects, each 50m in length, were used to measure the canopy cover of perennial plants encountered at 1 km intervals along the left (eastern) edge of each of the belt transects used for the special status plant monitoring (because of its large size, canopy cover of the annual species, *Dicoria cansecens*, was also measured). These line-intercept transects were positioned using a systematic sample with a random start. The 25m segments used to sample ASMAP and HENIT were used to determine the starting point for the first vegetation transect along each belt transect. There are 40 such 25m segments in each 1 km of the belt transect. One of the first 39 segments was randomly selected (because the line-intercept transect is 50m in length, use of the 40^{th} segment would result in the 50m transect running past the 1 km point). Additional transects were then run at 1 km from the first one.

The distance intercepted by the canopy of each perennial plant along each 50m line was recorded by species. The distance intercepted expressed in meters divided by the 50m length of the line gives an estimate of the proportion of line intercepted by the species. Multiplying the proportion by 100% converts it to a percent, which is the estimate of percent canopy cover for that species in the area sampled by the 50m line. The 50m lines were treated as the sampling units in estimating cover and confidence intervals for each sampling area. Weighted averaging was used to combine sampling area cover estimates into estimates for each management area and for the Dunes as a whole. Confidence intervals around estimated weighted mean cover values were calculated by weighting sampling area variance estimates and summing these as described in Schreuder et al. (2004, page 21). Because lines at least theoretically have no width, the population of lines that can be placed in a sampling area is infinite. Therefore, no finite population correction factor was applied to the estimates.

Except for the precipitation graphs, which were constructed using Microsoft Excel 2003, all graphs were constructed using SYSTAT version 10.2 (SYSTAT 2002).

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estimates of population densities and totals and their confidence intervals derived from these two commands were effectively equivalent.

Results

Transects were read by 12 teams of 3 individuals each. Monitoring began on February 15, 2005, and ended on April 26, 2005. Table 2 shows the number of transects read by sampling area during each week of the monitoring.

Table 2. Number of transects read each week during 2005 by sampling area.

Management and Sampling Area *	Number of Transects by Week **										
	1	2	3	4	5	6	7	8	9	10	11
MW 13	0	9	0	0	0	21	0	0	0	0	0
MW 14	0	0	0	0	4	26	0	0	0	0	0
Wilderness 15	0	0	9	6	7	2	0	0	1	0	0
Wilderness 16	0	0	2	5	9	2	3	0	4	0	0
Gecko 3	1	11	1	0	6	0	1	0	0	5	0
Gecko 4	0	4	3	0	7	0	9	0	0	2	0
Glamis 5	0	0	13	0	0	12	0	0	0	0	0
Glamis 6	0	0	15	0	0	10	0	0	0	0	0
AMA 7	0	0	0	13	0	0	11	11	0	0	3
AMA 8	0	0	5	0	12	5	0	10	0	0	1
AMA 17	0	0	0	1	10	0	0	15	1	14	1
AMA 18	0	0	0	11	0	0	11	0	0	20	0
Ogilby 19	0	0	0	12	0	0	10	0	8	0	13
Ogilby 20	0	0	0	0	9	0	0	11	11	0	12
Buttercup 11	0	27	0	0	1	0	0	1	0	0	0
Buttercup 12	0	0	0	0	8	0	0	0	22	0	0

* Sampling area numbers are as shown on Map 2. The name in front of the sampling area number corresponds to the management area within which the sampling area is located. Two management area names have been abbreviated as follows: MW = Mammoth Wash; AMA = Adaptive Management Area.
** Based on starting date of transects. In a few cases the ending date of the transect may be > 1 week from starting date. Week 1 = Feb. 15-20; week 2 = Feb. 21-27; week 3 = Feb. 28-Mar. 6; week 4 = Mar. 7-13; week 5 = Mar. 14-20; week 6 = Mar. 21-27; week 7 = Mar. 28-Apr. 3; week 8 = Apr. 4-10; week 9 = Apr. 11-17; week 10 = Apr. 18-24; week 11 = Apr. 25-May 1.

Weather

Because weather is critical to the interpretation of these monitoring data, it will be discussed first.

Growing Season Precipitation. Growing season precipitation is defined as the amount of precipitation between the months of September 1 and June 30, which corresponds to the definition used by Sneva and Hyder (1962) in the Intermountain West (they term this period the "crop-year"). Although some rain often falls in the Dunes in the months of July and August as a result of tropical storms from the Gulf of California, this rain likely does not promote germination and growth of HENIT because of the intense heat during those months.

Table 3 shows the total growing season precipitation recorded by the two RAWS stations for growing seasons 2002-2003, 2003-2004, and 2004-2005. Figures 1, 2, and 3 show the monthly precipitation totals recorded by each of the stations for these growing seasons.

Table 3. Growing season (September-June) precipitation from the two remote area weather stations (RAWS) in the Algodones Dunes. The long-term growing season average of the WRCC stations in the vicinity of the dunes is given for comparison. All units are in inches.

Growing Season	Cahuilla RAWS	Buttercup RAWS	Average of the two RAWS	Long-term average of all WRCC Stations
2002-2003	2.68	1.15	1.92	2.50
2003-2004	2.20	2.46	2.33	2.50
2004-2005	4.87	4.68	4.78	2.50

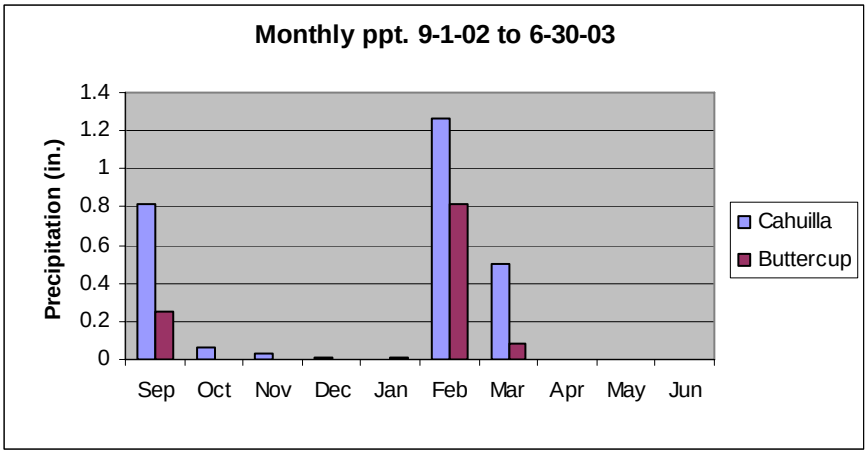

Figure 1. Monthly total precipitation between September 2002 and June 2003 for the two RAWS stations in the Algodones Dunes.

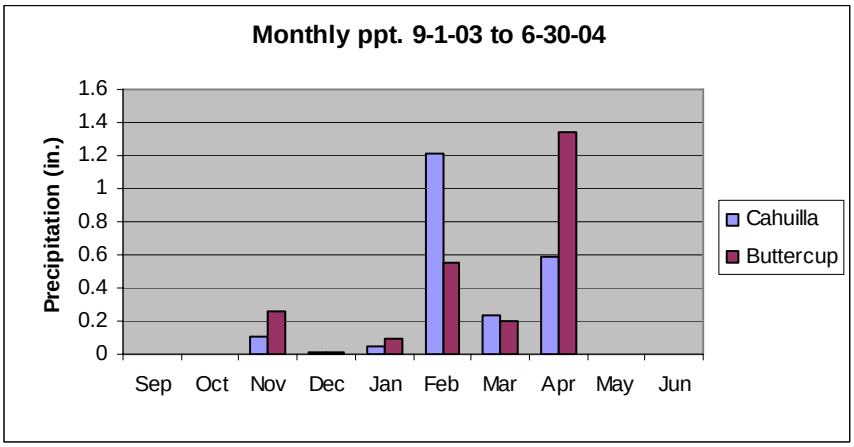

Figure 2. Monthly total precipitation between September 2003 and June 2004 for the two RAWS stations in the Algodones Dunes.

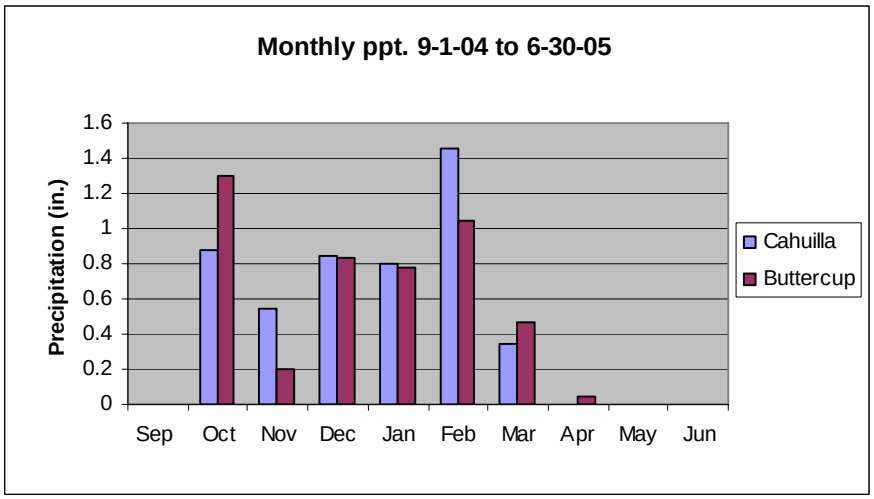

Figure 3. Monthly total precipitation between September 2004 and June 2005 for the two RAWS stations in the Algodones Dunes.

Helianthus niveus* ssp. *tephrodes

Seedlings. As stated in the Methods section, seedling counts of HENIT were discontinued because it became too laborious to count seedlings, even with a 5m-wide, as opposed to a 25m-wide, belt. Before the decision was made to discontinue seedling counts, a total of 57 belt transects in 5 of the 16 sampling areas were counted. Table 4 below shows seedling population estimates for these 5 sampling areas. These estimates should be viewed only as a possible indication of the magnitude of the number of seedlings in these sampling areas and in the Dunes as a whole in 2005. Only the estimate for Sampling Area 11 in the Buttercup Management Area is likely truly representative of that sampling area because seedlings were counted in all but four of the planned 29 transects in that sampling area. The estimates for the other sampling areas are based on far fewer transects than planned and the interspersion of these transects within these sampling areas was poor.[4] Additionally, confidence intervals are relatively wide around each of the estimates primarily as a result of sample sizes that were much smaller than those used to estimate adult HENIT plants.

Table 4. HENIT seedling population estimates for the 5 sampling areas that were sampled before seedling counts were discontinued in 2005. See text concerning reliability of these estimates.

Sampling Area	Number of Transects Sampled	Population Estimate	95% Confidence Interval	
			Lower	Upper
Mammoth Wash 13	9	285,148	142,970	427,326
Wilderness 15	8	31,008	219	82,015
Gecko 3	8	1,095,094	211,953	1,978,235
Glamis 5	7	732,145	6,710	1,483,164
Buttercup 11	25	714,714	301,808	1,127,620
Total	57	2,858,109	1,800,124	3,916,093

Adult plants. Figures 3 and 4 show the estimates of density (number of plants/hectare) and total population size, respectively, of HENIT in each of the management areas and the contribution of the two stage classes (nonflowering adults and flowering) to the totals. Table 5 shows the actual density and population estimates for each of the 5 categories for each management area and the Dunes as a whole. Figures 5-14 are dot graphs and 95% confidence intervals showing estimates of HENIT density (plants/ha) and total population size for each of the 5 categories for which data were collected. For each of these categories there is a pair of graphs, the first one showing estimates of density (number of plants/hectare) and the second one showing estimates of total

[4] Interspersion was poor because transects were sampled beginning at one end or the other of the baseline that forms the northern boundary of each sampling area. Discontinuing the seedling counts left relatively large areas of each sampling area unsampled. For example, the 8 transects sampled in Sampling Area 15 in the Wilderness Management Area were all located on the western edge of that sampling area, whereas the 9 transects sampled in Sampling Area 13 in the Mammoth Wash Management Area were all located on the eastern edge of that sampling area.

population size. Density estimates are shown for each management area and the Dunes as a whole. Population estimates are shown for each management area.

Figures 17 and 18 compare the density and total population size estimates, respectively, for each of the seven management areas and the entire dunes in 2004 and 2005 and for the Wilderness and Gecko management areas in 2003 (only the Wilderness and Gecko management areas were sampled in 2003 as part of a pilot sampling effort).

Maps 3-7 show the distribution and abundance of HENIT in all of the 25m x 25m cells sampled in 2005 as follows:

Map 3: Total of nonflowering adult and flowering HENIT individuals
Map 4: Nonflowering adult HENIT individuals.
Map 5: Flowering HENIT individuals.
Map 6: HENIT individuals showing evidence of OHV damage.
Map 7: HENIT individuals showing evidence of damage from sources other than OHVs.

Map 8 shows the estimated total adult HENIT density in each of the 16 sampling area.

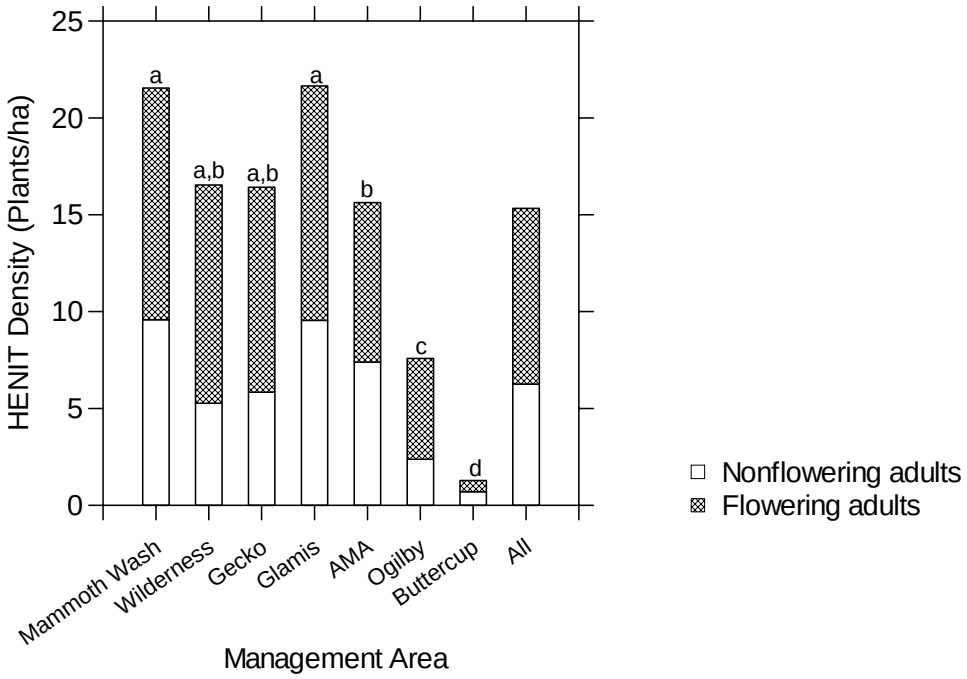

Figure 3. HENIT estimated density (plants/ha) for each of the management areas and the Dunes as a whole ("all") in spring 2005. Densities of management areas with different letters at the tops of the bars are significantly different at $P<0.05$.

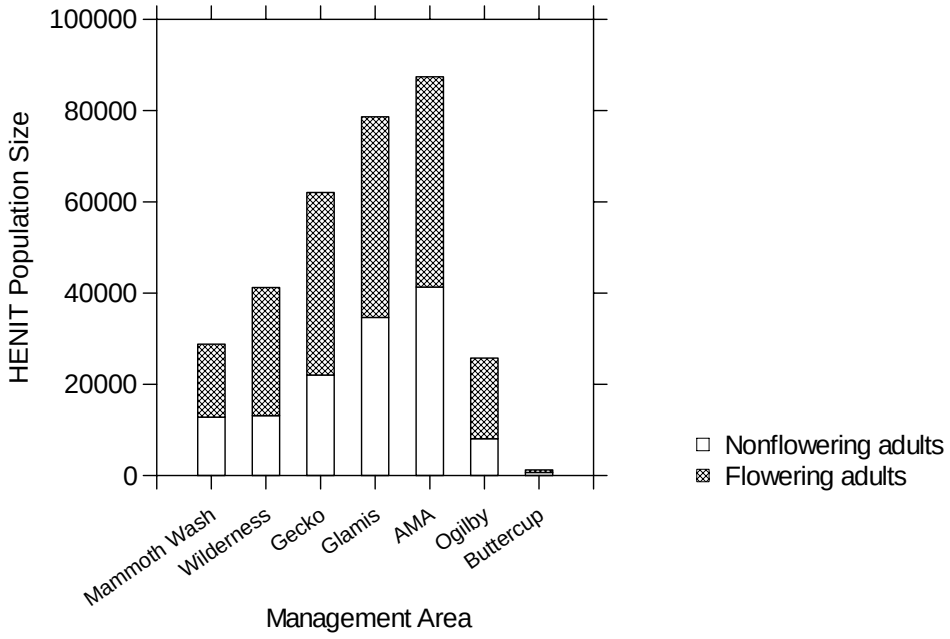

Figure 4. HENIT estimated population size for each of the management areas in spring 2005.

Table 5. Spring 2005 population and density estimates for HENIT in the 7 management areas of the Algodones Dunes and the entire dunes. Estimates from survey module of Stata 9.

Mammoth Wash

Category	Density Estimate (plants/ha)	95% Confidence Limits		Population Estimate	95% Confidence Limits		Precision (+/- percent of estimate)
		Lower	Upper		Lower	Upper	
Nonflowering adults	9.582	6.167	12.996	12,805	8,241	17,369	35.64%
Flowering adults	11.956	9.235	14.677	15,978	12,342	19,615	22.76%
Total number of plants	21.538	16.177	26.898	28,784	21,619	35,948	24.89%
Plants with OHV damage	0.069	0.034	0.111	92	46	149	61.79%
Plants with other damage	0.238	0.119	0.410	318	159	548	72.31%

Wilderness

Category	Density Estimate (plants/ha)	95% Confidence Limits		Population Estimate	95% Confidence Limits		Precision (+/- percent of estimate)
		Lower	Upper		Lower	Upper	
Nonflowering adults	5.272	2.596	7.947	13,142	6,472	19,811	50.75%
Flowering adults	11.260	8.182	14.337	28,070	20,398	35,741	27.33%
Total number of plants	16.531	11.739	21.324	41,211	29,264	53,159	28.99%
Plants with OHV damage	0.000	0.000	0.000	0	0	0	0.00%
Plants with other damage	0.453	0.161	0.936	1,130	401	2,334	106.62%

Gecko

Category	Density Estimate (plants/ha)	95% Confidence Limits		Population Estimate	95% Confidence Limits		Precision (+/- percent of estimate)
		Lower	Upper		Lower	Upper	
Nonflowering adults	5.835	2.892	8.777	22,056	10,931	33,181	50.44%
Flowering adults	10.581	8.473	12.689	39,999	32,030	47,967	19.92%
Total number of plants	16.415	12.451	20.380	62,055	47,069	77,041	24.15%
Plants with OHV damage	0.111	0.032	0.191	421	119	723	71.71%
Plants with other damage	0.587	0.193	0.982	2,220	729	3,711	67.16%

Table 5. Spring 2005 population and density estimates for HENIT in the 7 management areas of the Algodones Dunes and the entire dunes. Estimates from survey module of Stata 9.

Glamis

Category	Density Estimate (plants/ha)	95% Confidence Limits		Population Estimate	95% Confidence Limits		Precision (+/- percent of estimate)
		Lower	Upper		Lower	Upper	
Nonflowering adults	9.547	6.609	12.486	34,687	24,012	45,363	30.78%
Flowering adults	12.101	10.095	14.108	43,966	36,675	51,256	16.58%
Total number of plants	21.649	17.714	25.584	78,653	64,357	92,949	18.18%
Plants with OHV damage	0.304	0.181	0.428	1,105	656	1,554	40.61%
Plants with other damage	1.574	0.616	2.532	5,718	2,237	9,199	60.87%

Adaptive Management Area

Category	Density Estimate (plants/ha)	95% Confidence Limits		Population Estimate	95% Confidence Limits		Precision (+/- percent of estimate)
		Lower	Upper		Lower	Upper	
Nonflowering adults	7.386	5.690	9.082	41,324	31,834	50,814	22.97%
Flowering adults	8.237	7.468	9.006	46,085	41,782	50,387	9.34%
Total number of plants	15.623	13.620	17.627	87,409	76,201	98,617	12.82%
Plants with OHV damage	0.016	0.007	0.028	90	38	156	74.38%
Plants with other damage	0.506	0.347	0.666	2,831	1,939	3,724	31.53%

Ogilby

Category	Density Estimate (plants/ha)	95% Confidence Limits		Population Estimate	95% Confidence Limits		Precision (+/- percent of estimate)
		Lower	Upper		Lower	Upper	
Nonflowering adults	2.379	1.886	2.873	8,083	6,407	9,759	20.73%
Flowering adults	5.206	4.772	5.640	17,684	16,210	19,158	8.34%
Total number of plants	7.585	6.889	8.281	25,767	23,401	28,132	9.18%
Plants with OHV damage	0.018	0.011	0.025	61	38	85	38.60%
Plants with other damage	0.327	0.229	0.425	1,111	778	1,443	29.94%

Table 5. Spring 2005 population and density estimates for HENIT in the 7 management areas of the Algodones Dunes and the entire dunes. Estimates from survey module of Stata 9.

Buttercup

Category	Density Estimate (plants/ha)	95% Confidence Limits		Population Estimate	95% Confidence Limits		Precision (+/- percent of estimate)
		Lower	Upper		Lower	Upper	
Nonflowering adults	0.697	0.386	1.008	678	376	981	44.58%
Flowering adults	0.581	0.477	0.685	565	464	666	17.93%
Total number of plants	1.278	0.927	1.630	1,243	901	1,585	27.50%
Plants with OHV damage	0.170	0.063	0.285	166	61	277	67.03%
Plants with other damage	0.047	0.024	0.070	46	24	68	48.15%

Entire dunes

Category	Density Estimate (plants/ha)	95% Confidence Limits		Population Estimate	95% Confidence Limits		Precision (+/- percent of estimate)
		Lower	Upper		Lower	Upper	
Nonflowering adults	6.261	5.340	7.182	132,776	113,245	152,307	14.71%
Flowering adults	9.070	8.402	9.738	192,346	178,176	206,515	7.37%
Total number of plants	15.331	14.061	16.600	325,122	298,193	352,051	8.28%
Plants with OHV damage	0.091	0.065	0.117	1,935	1,388	2,482	28.27%
Plants with other damage	0.631	0.442	0.819	13,373	9,370	17,376	29.93%

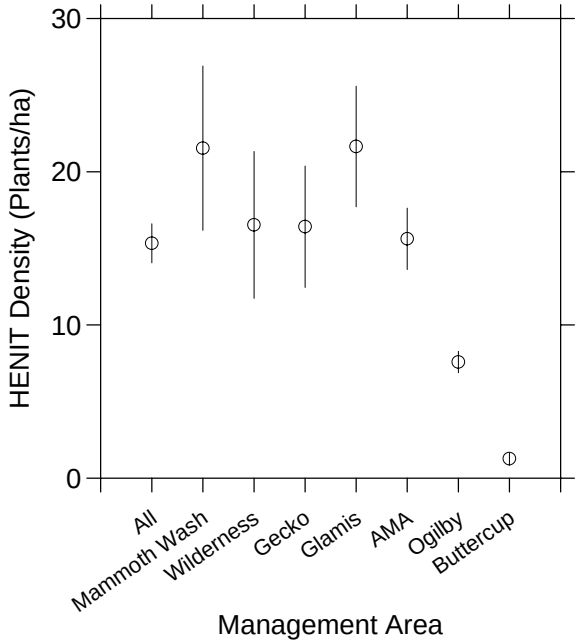

Figure 5. Density (plants/ha) of the total of adult nonflowering and adult flowering HENIT plants in spring 2005 for each of the management areas and the Dunes as a whole ("All"). Error bars are 95% confidence intervals.

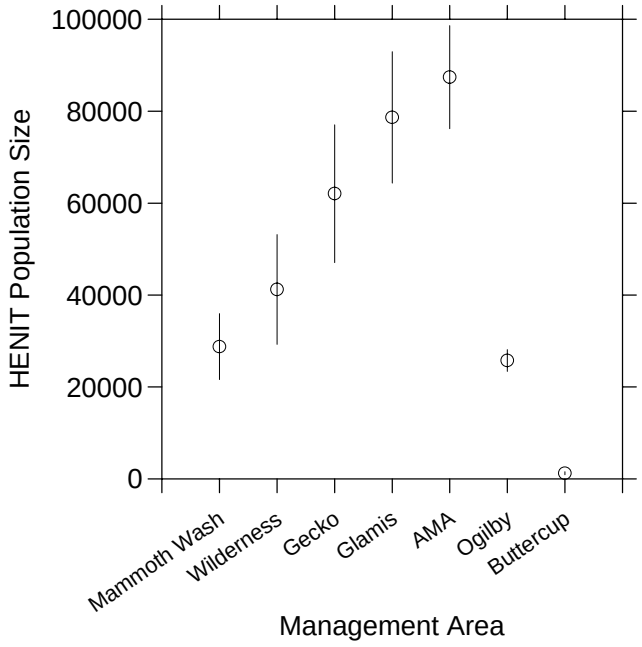

Figure 6. Population size of the total of adult nonflowering and adult flowering HENIT plants in spring 2005 for each of the management areas. Error bars are 95% confidence intervals.

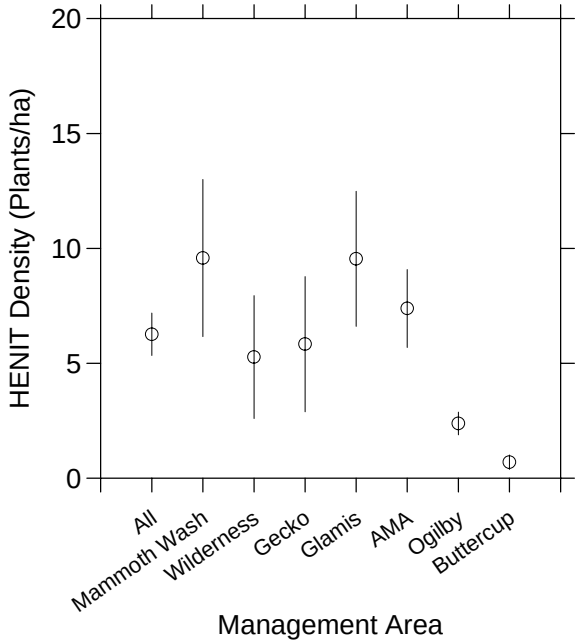

Figure 7. Density (plants/ha) of adult nonflowering HENIT plants in spring 2005 for each of the management areas and the Dunes as a whole ("All"). Error bars are 95% confidence intervals.

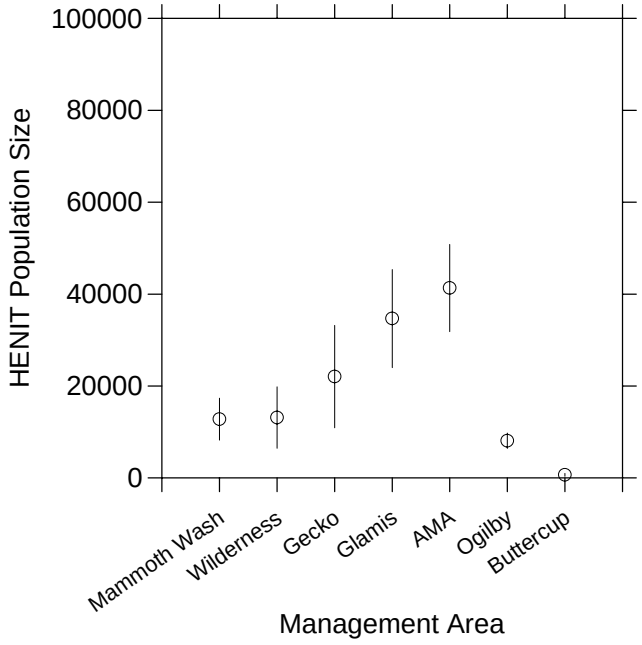

Figure 8. Population size of adult nonflowering HENIT plants in spring 2005 for each of the management areas. Error bars are 95% confidence intervals.

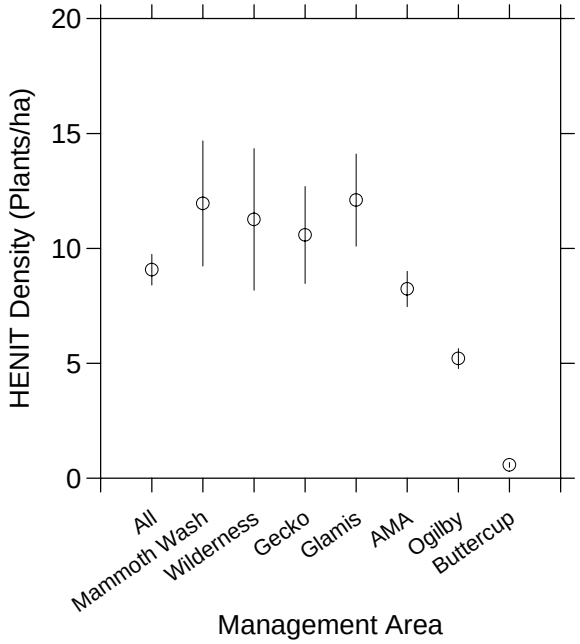

Figure 9. Density (plants/ha) of adult flowering HENIT plants in spring 2005 for each of the management areas and the Dunes as a whole ("All"). Error bars are 95% confidence intervals.

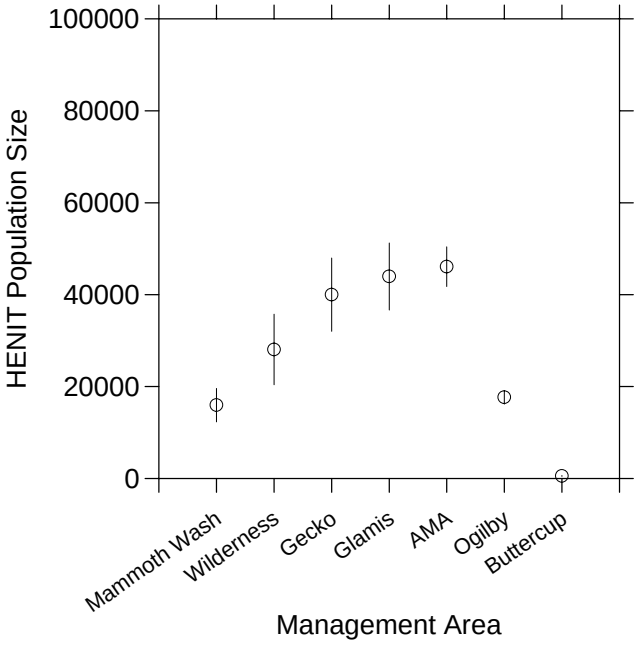

Figure 10. Population size of adult flowering HENIT plants in spring 2005 for each of the management areas. Error bars are 95% confidence intervals.

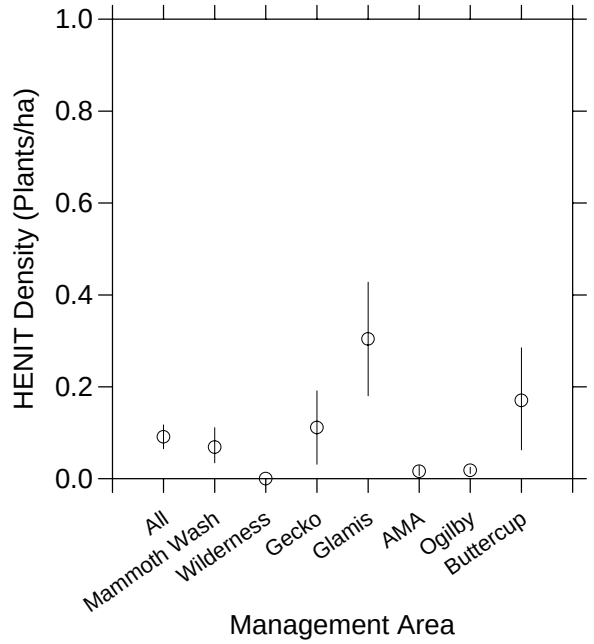

Figure 11. Density (plants/ha) of HENIT plants showing OHV damage in spring 2005 for each of the management areas and the Dunes as a whole ("All"). Error bars are 95% confidence intervals.

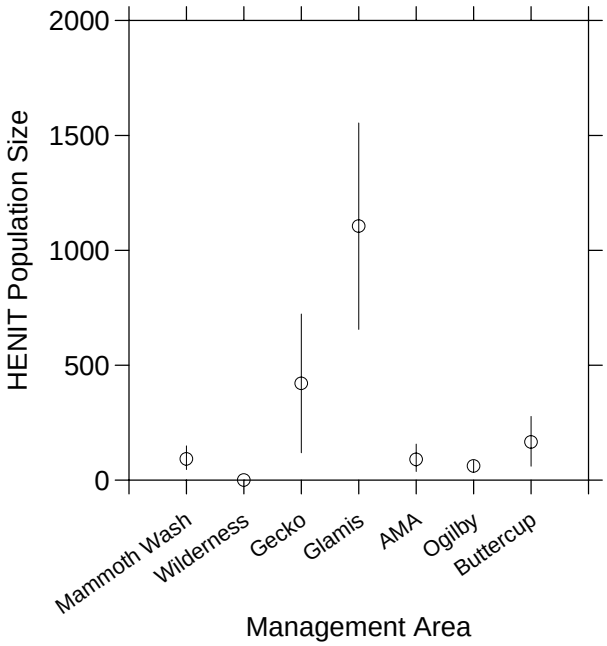

Figure 12. Population size of HENIT plants showing OHV damage in spring 2005 for each of the management areas. Error bars are 95% confidence intervals.

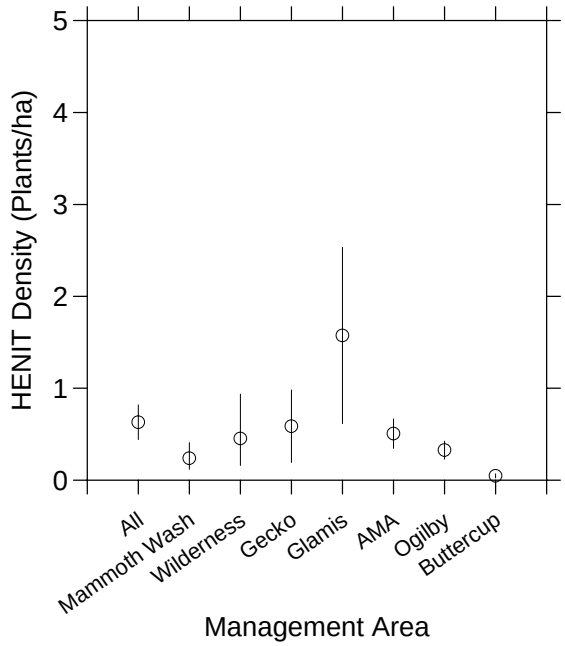

Figure 13. Density (plants/ha) of HENIT plants showing non-OHV damage in spring 2005 for each of the management areas and the Dunes as a whole ("All"). Error bars are 95% confidence intervals.

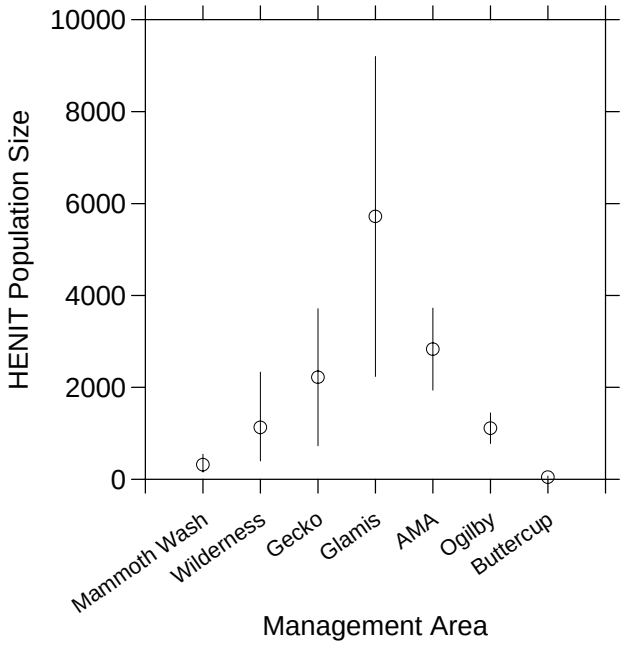

Figure 14. Population size of HENIT plants showing non-OHV damage in spring 2005 for each of the management areas. Error bars are 95% confidence intervals.

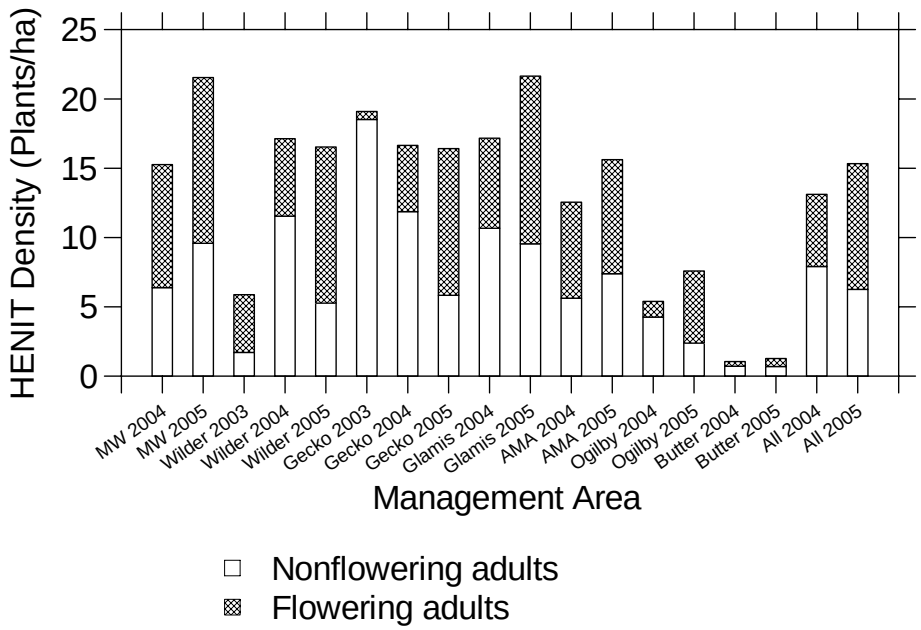

Figure 17. Density (plants/ha) of adult nonflowering and adult flowering HENIT plants density in each of the seven management areas and the entire dunes in 2004 and 2005 and in the Wilderness and Gecko management areas in 2003. Management area abbreviations are as follows: MW = Mammoth Wash; Wilder = Wilderness; AMA = Adaptive Management Area; Butter = Buttercup; All = entire dunes.

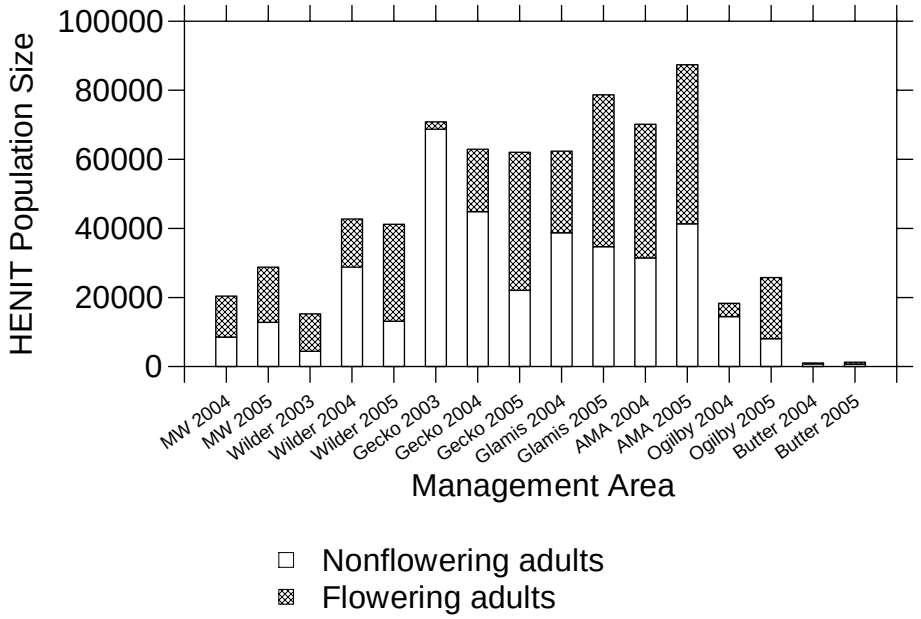

Figure 18. HENIT population size (total of nonflowering adult and flowering adult plants) in each of the seven management areas and the entire dunes in 2004 and 2005 and in the Wilderness and Gecko management areas in 2003. See Figure 1 for abbreviations of management areas.

Psammophytic Vegetation

Figure 19 shows the mean canopy cover of all perennial plants in each of the management areas of the Dunes in 2005. Table 6 shows cover values by species for each of the management areas and for the Dunes as a whole. Shrubs are shown in descending order of cover for each management area and the entire Dunes, using the symbols recognized by the Plants Database (USDA, NRCS 2005). A key to the symbols is given in Appendix 1. Total cover is the additive cover of all perennial species (and does not include cover of the annual *Dicoria cansecens*).

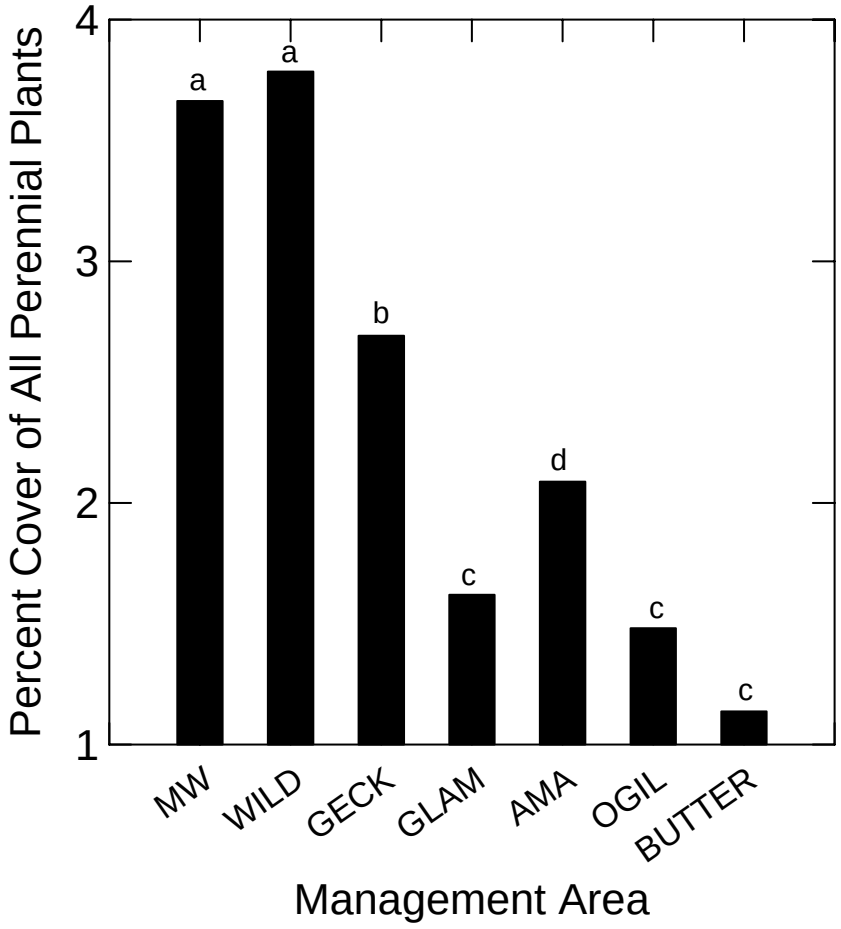

Figure 19. Mean canopy cover of all perennial plants in each of the management areas of the Dunes in spring 2005. Cover of management areas with different letters at the tops of the bars are significantly different at $P<0.05$.

Table 6. Percent cover by species by management area and the entire Dunes. Total cover is the additive cover of all perennial plants (and doesn't include the cover of DICA4 because it is an annual plant). The robust annual DICA4 is included in the table because of its relatively high cover in 2005. Species are listed in order of descending cover by management area. Perennial plants showing 0.00% cover were intercepted but had cover values less than 0.005%.

Mammoth Wash (n = 276)

		95% Confidence Limits (%)		
Species	Mean Cover (%)	Lower	Upper	Precision (+/- % of mean)
Total Cover	3.66	3.20	4.13	13
ERDE9	2.02	1.68	2.36	17
HENIT	0.77	0.49	1.05	37
DICA4	0.20	0.11	0.28	44
CRWI2	0.19	0.11	0.27	41
PAARG	0.17	0.11	0.23	33
PETHT	0.14	0.07	0.20	46
PSEM	0.08	0.00	0.17	107
LATR2	0.08	0.01	0.15	88
EPTR	0.07	0.01	0.13	83
PAFL6	0.05	0.00	0.11	118
ASMAP	0.04	0.01	0.08	72
TIPL2	0.04	0.01	0.07	84
AMDU2	0.00	0.00	0.01	179

Wilderness (n = 360)

		95% Confidence Limits (%)		
Species	Mean Cover (%)	Lower	Upper	Precision (+/- % of mean)
Total Cover	3.78	3.35	4.22	11
ERDE9	1.77	1.48	2.07	17
HENIT	0.62	0.38	0.86	38
DICA4	0.46	0.34	0.58	26
PAARG	0.39	0.29	0.49	26
CRWI2	0.31	0.20	0.43	37
TIPL2	0.22	0.14	0.31	39
EPTR	0.21	0.11	0.31	47
PETHT	0.09	0.05	0.13	47
LATR2	0.06	0.00	0.12	99
ASMAP	0.06	0.02	0.09	61
PSEM	0.04	0.00	0.09	155
CHLIA	0.01	0.00	0.02	140

Table 6. Percent cover by species by management area and the entire Dunes. Total cover is the additive cover of all perennial plants (and doesn't include the cover of DICA4 because it is an annual plant). The robust annual DICA4 is included in the table because of its relatively high cover in 2005. Species are listed in order of descending cover by management area. Perennial plants showing 0.00% cover were intercepted but had cover values less than 0.005%.

Gecko (n = 327)

		95% Confidence Limits (%)		
Species	Mean Cover (%)	Lower	Upper	Precision (+/- % of mean)
Total Cover	2.69	2.31	3.07	14
DICA4	1.05	0.79	1.30	24
ERDE9	0.89	0.68	1.11	24
CRWI2	0.79	0.61	0.98	24
HENIT	0.47	0.32	0.61	32
TIPL2	0.18	0.11	0.25	39
PAARG	0.13	0.07	0.19	48
EPTR	0.12	0.04	0.20	67
PETHT	0.07	0.02	0.12	70
ASMAP	0.04	0.02	0.05	52
ASCLE	0.00	0.00	0.01	197

Glamis (n = 306)

		95% Confidence Limits (%)		
Species	Mean Cover (%)	Lower	Upper	Precision (+/- % of mean)
Total Cover	1.62	1.26	1.98	22
DICA4	1.31	1.01	1.61	23
ERDE9	0.55	0.38	0.73	32
HENIT	0.54	0.34	0.73	36
CRWI2	0.14	0.04	0.24	72
LATR2	0.13	0.04	0.22	71
PAARG	0.13	0.07	0.19	47
PETHT	0.07	0.01	0.13	88
TIPL2	0.04	0.01	0.08	76
ASMAP	0.01	0.00	0.03	130
EPTR	0.01	0.00	0.02	163

Table 6. Percent cover by species by management area and the entire Dunes. Total cover is the additive cover of all perennial plants (and doesn't include the cover of DICA4 because it is an annual plant). The robust annual DICA4 is included in the table because of its relatively high cover in 2005. Species are listed in order of descending cover by management area. Perennial plants showing 0.00% cover were intercepted but had cover values less than 0.005%.

Adaptive Management Area (n = 996)

		95% Confidence Limits (%)		
Species	Mean Cover (%)	Lower	Upper	Precision (+/- % of mean)
Total Cover	2.09	1.90	2.28	9
ERDE9	0.77	0.64	0.89	16
DICA4	0.60	0.51	0.68	14
HENIT	0.53	0.44	0.61	17
CRWI2	0.24	0.18	0.30	24
PAARG	0.23	0.18	0.27	19
PETHT	0.09	0.06	0.13	38
ASMAP	0.07	0.05	0.09	28
LATR2	0.06	0.03	0.09	53
TIPL2	0.05	0.03	0.08	43
EPTR	0.05	0.03	0.08	52
AMDU2	0.00	0.00	0.00	196
PSEM	0.00	0.00	0.00	196

Ogilby (n = 660)

		95% Confidence Limits (%)		
Species	Mean Cover (%)	Lower	Upper	Precision (+/- % of mean)
Total Cover	1.48	1.27	1.69	14
DICA4	1.21	1.00	1.43	18
ERDE9	0.42	0.29	0.54	30
LATR2	0.39	0.27	0.51	30
PAARG	0.21	0.15	0.26	28
HENIT	0.20	0.13	0.27	33
CRWI2	0.09	0.04	0.14	196
TIPL2	0.08	0.05	0.12	44
ASMAP	0.04	0.02	0.06	46
EPTR	0.03	0.00	0.05	83
PETHT	0.02	0.00	0.04	87
AMDU2	0.00	0.00	0.00	196

Table 6. Percent cover by species by management area and the entire Dunes. Total cover is the additive cover of all perennial plants (and doesn't include the cover of DICA4 because it is an annual plant). The robust annual DICA4 is included in the table because of its relatively high cover in 2005. Species are listed in order of descending cover by management area. Perennial plants showing 0.00% cover were intercepted but had cover values less than 0.005%.

Buttercup (n = 182)

		95% Confidence Limits (%)		
Species	Mean Cover (%)	Lower	Upper	Precision (+/- % of mean)
Total Cover	1.14	0.78	1.49	31
LATR2	0.73	0.42	1.05	43
DICA4	0.38	0.22	0.53	42
PAARG	0.20	0.09	0.32	58
ERDE9	0.07	0.02	0.11	71
HENIT	0.06	0.00	0.15	155
EPTR	0.05	0.00	0.11	117
CRWI2	0.02	0.00	0.05	190
ASMAP	0.01	0.00	0.03	197

Entire Dunes (n = 3107)

		95% Confidence Limits (%)		
Species	Mean Cover (%)	Lower	Upper	Precision (+/- % of mean)
Total Cover	2.27	2.15	2.40	6
ERDE9	0.86	0.79	0.94	9
DICA4	0.85	0.77	0.93	10
HENIT	0.47	0.41	0.53	13
CRWI2	0.29	0.25	0.34	15
PAARG	0.20	0.18	0.23	12
LATR2	0.15	0.12	0.18	21
TIPL2	0.10	0.08	0.12	20
EPTR	0.07	0.05	0.09	29
PETHT	0.07	0.05	0.09	25
ASMAP	0.04	0.03	0.05	20
PSEM	0.01	0.00	0.02	88
PAFL6	0.00	0.00	0.01	118
CHLIA	0.00	0.00	0.00	139
AMDU2	0.00	0.00	0.00	127
ASCLE	0.00	0.00	0.00	196

Figures 20-23 show mean cover values for total cover and for the three perennial species with the highest Dunes-wide cover values for each of the seven management areas and the entire dunes in 2004 and 2005 and in the Wilderness and Gecko management areas in 2003. Figure 24 shows similar data for the robust annual *Dicoria canescens*. Note that the cover values of *Dicoria* are not included in the total perennial vegetation cover graphed in Figure 20.

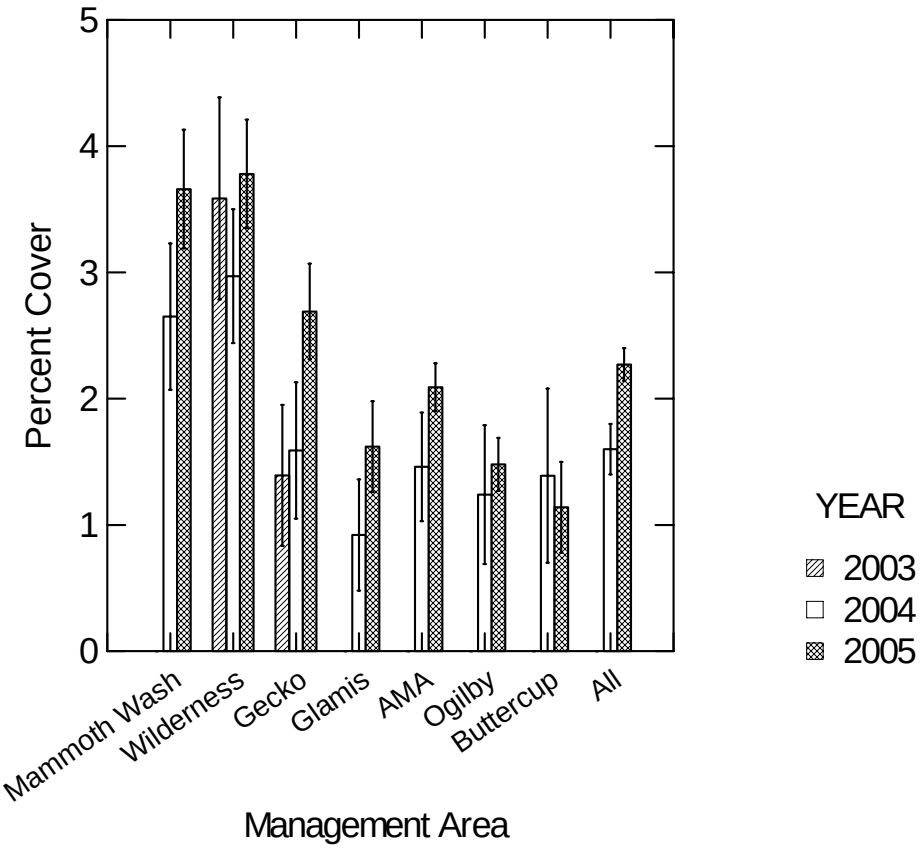

Figure 20. Mean cover of all perennial plants in each of the management areas and the entire dunes ("all") in 2004 and 2005 and in the Wilderness and Gecko management areas in 2003. Error bars are 95% confidence intervals.

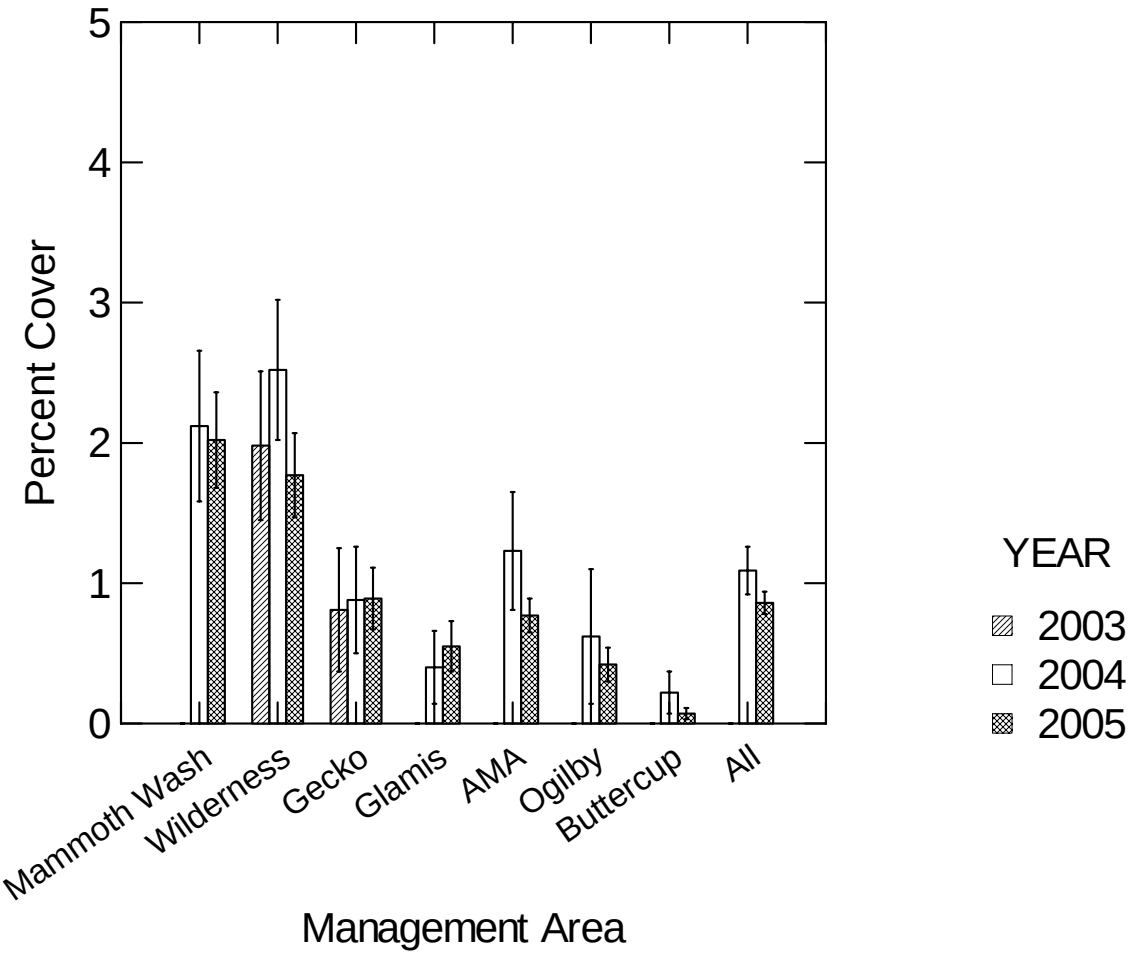

Figure 21. Mean cover of *Eriogonum deserticola* (ERDE9) in each of the management areas and the entire dunes ("all") in 2004 and 2005 and in the Wilderness and Gecko management areas in 2003. Error bars are 95% confidence intervals.

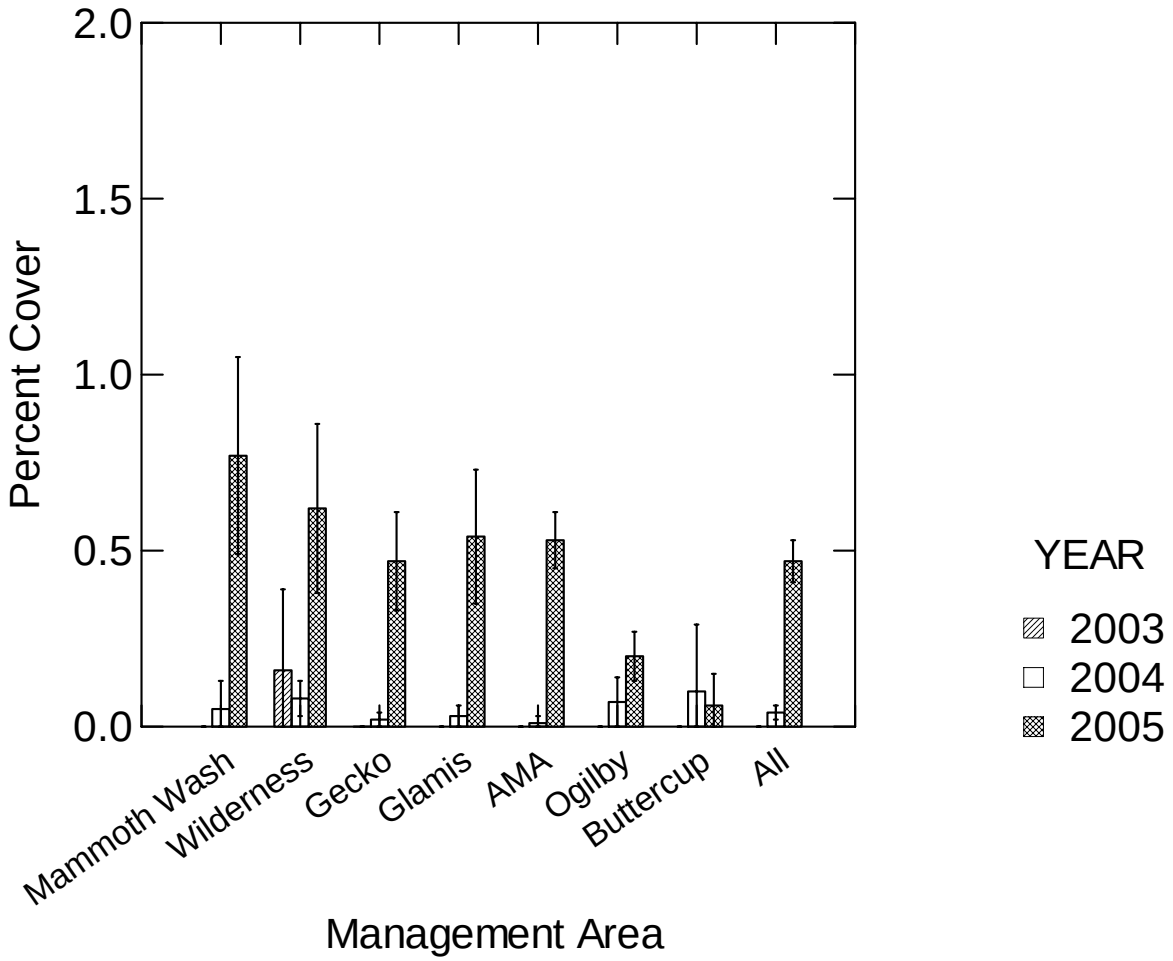

Figure 22. Mean cover of *Helianthus niveus* ssp. *tephrodes* (HENIT) in each of the management areas and the entire dunes ("all") in 2004 and 2005 and in the Wilderness and Gecko management areas in 2003. Error bars are 95% confidence intervals.

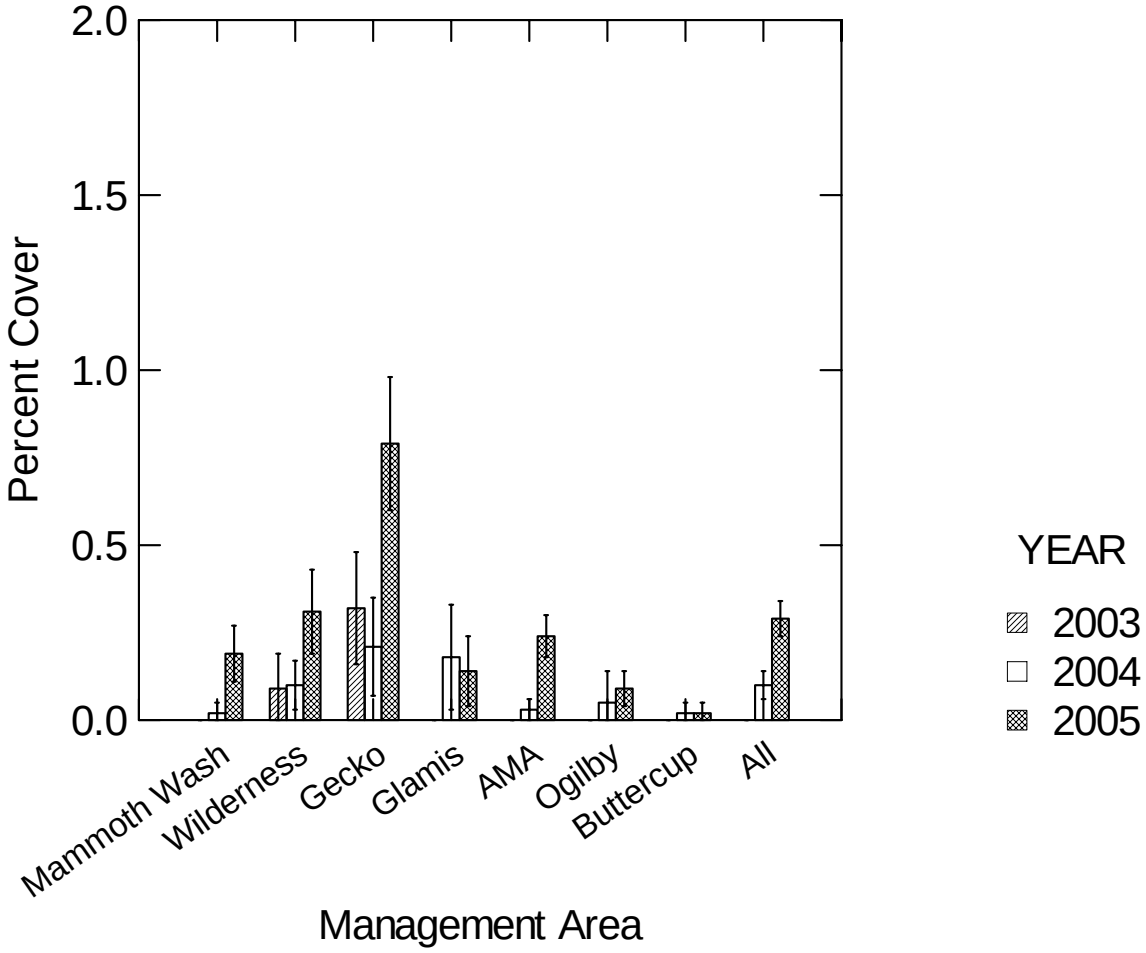

Figure 23. Mean cover of *Croton wigginsii* (CRWI2) in each of the management areas and the entire dunes ("all") in 2004 and 2005 and in the Wilderness and Gecko management areas in 2003. Error bars are 95% confidence intervals.

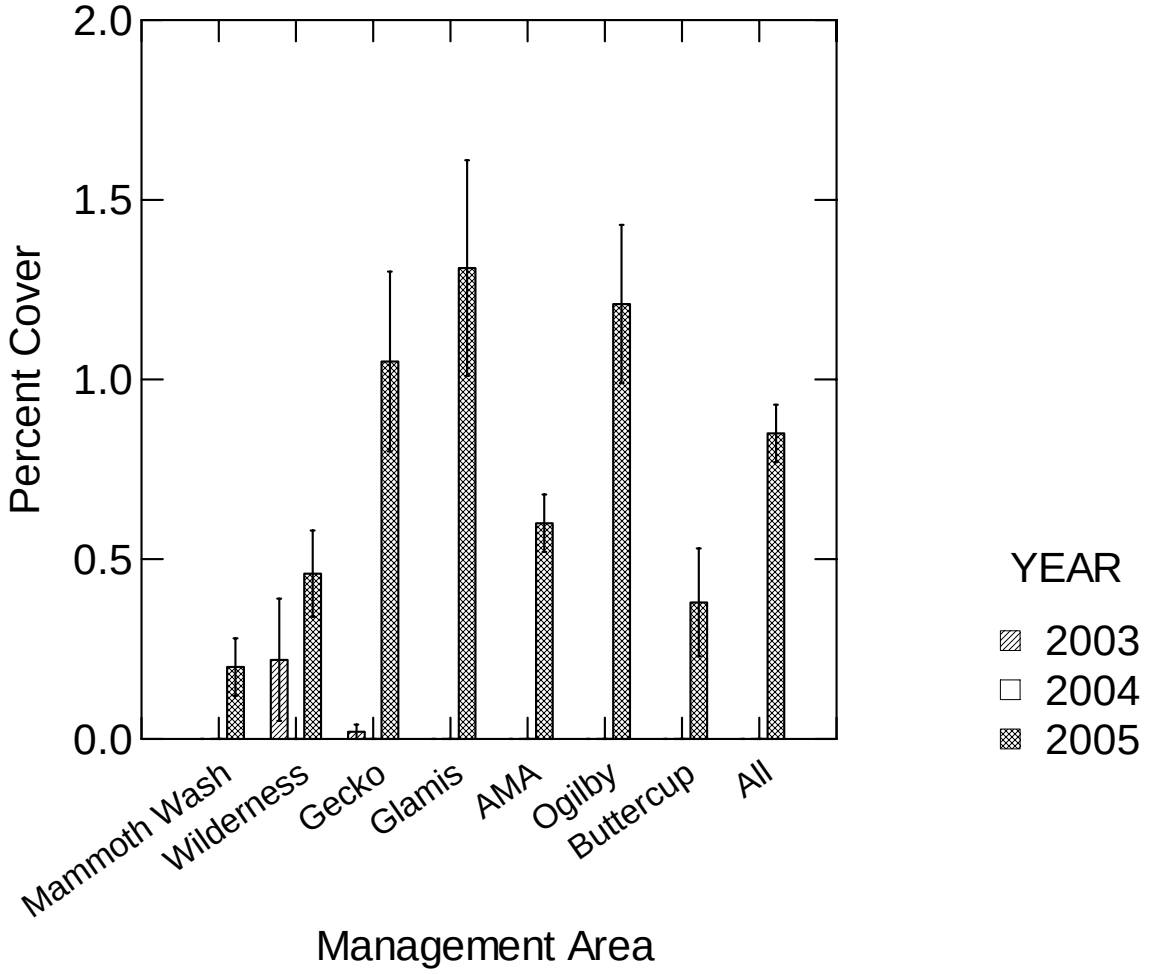

Figure 24. Mean cover of the annual *Dicoria canescens* (DICA4) in each of the management areas and the entire dunes ("all") in 2004 and 2005 and in the Wilderness and Gecko management areas in 2003. Error bars are 95% confidence intervals. Note that except for a small amount of cover in the Gecko Management Area in 2003, cover of this species was essentially zero in 2003 and 2004, probably the result of the much lower and poorly distributed growing season precipitation for those two years as compared to 2005.

Discussion

Helianthus niveus* ssp. *tephrodes

Distribution and abundance. Separate discussions are provided for adult and seedling plants.

Adult plants. There were an estimated 325,122 adult HENIT plants throughout the seven management areas of the Dunes in 2005. This translates into an estimated density of 15.33 adult plants/hectare, but as Figures 3 and 4 and Map 3 show, HENIT was not uniformly distributed throughout these seven management areas.

Because management areas are different sizes, density (plants/ha) is a better parameter than population size to use to compare management areas.[5] HENIT adult plant densities between management areas were compared using pairwise t tests.[6] Figure 3 shows the results of these t tests. The highest estimated HENIT density was in the Glamis Management Area (21.65 adult plants/ha) and the lowest estimated density was in the Buttercup Management Area (1.28 adult plants/ha), which had a significantly lower density that any of the other management areas. The Mammoth Wash Management Area (21.5 adult plants/ha) had the second highest density and was not significantly different from the Glamis Management Area. The Wilderness (16.53 adult plants/ha) and Gecko (16.42 adult plants/ha) management areas had the third and fourth highest densities, respectively, but neither of these areas differed significantly from either the Mammoth Wash or Glamis management areas. The Adaptive Management Area (15.62 adult plants/ha) had the fifth highest density; its density was significantly different from the Mammoth Wash and Glamis management areas, but was not significantly different from the Wilderness and Gecko management areas. The Ogilby Management Area (7.59 plants/ha) had the sixth highest density and was significantly different from all of the other management areas.

The Dunes-wide total population estimate of adult HENIT plants for 2005 was 325,122 plants. The Adaptive Management Area with an estimated 87,409 adult plants accounted for the highest percentage (26.9%) of this total. Totals and percentages in descending order for the other management areas are as follows: Glamis (78,653 adult plants, 24.2%), Gecko (62,055 adult plants, 19.1%), Wilderness (41,211 adult plants, 12.7%), Mammoth Wash (28,784 adult plants, 12.7%), Ogilby (25,767 adult plants, 7.9%), and Buttercup (1,243 adult plants, 0.4%). Note that because of differences in the sizes of the management areas, this order is different from the order based on density.

The distribution of Peirson's milk-vetch in 2005 showed a marked west to east gradient in the numbers of plants, with more plants occupying the western side of the area sampled (Willoughby

[5] The use of density expressed as the number of plants per hectare should not in any way imply that HENIT is uniformly distributed throughout a management area, which is definitely not the case. In fact, the highly clumped distribution exhibited by the species led to the use of stratification and very long belt transects in order to more efficiently estimate the number of plants. Density is used here as a means of standardizing the estimates for different-sized management areas in order to make meaningful comparisons between these areas.

[6] No corrections (such as the Bonferroni correction) were applied to the *P* values from these tests to control for multiple testing because these were planned comparisons and because recent researchers have shown these corrections to be counterproductive (see, for example, Cabin and Mitchell 2000, Moran 2003, Nakagawa 2004, and Perneger 1998).

2005c). For example, the density of Peirson's milk-vetch was lowest in the Glamis Management Area, both of which's sampling areas are on the eastern side of the area sampled; its densities in the eastern sampling areas were much lower than the densities in the western sampling areas of the Adaptive Management Area, Ogilby, and Buttercup management areas. Except in the Adaptive Management Area, where the two eastern sampling areas have lower adult HENIT densities than the two western sampling areas (Map 8), no such west to east gradient is apparent in the densities recorded for adult HENIT in 2005. In fact, the Glamis Management Area had the highest adult HENIT density in 2005, though as noted above the Glamis density did not differ significantly from the densities of the Mammoth Wash, Wilderness, or Gecko management areas. There does, however, appear to be something of a north-south gradient in adult HENIT densities, at least in the southernmost part of the Dunes. The adult HENIT density of the Ogilby Management Area is significantly lower than the management areas to the north, and the density in the Buttercup Management Area in the extreme southern part of the Dunes is significantly lower than the Ogilby density.

Only an estimated 1,243 adult HENIT plants occurred in the Buttercup Management Area in 2005. This low number may well be the result of the concentrated OHV disturbance that that management area experiences because of its relatively small size and proximity to staging areas along Interstate 8. The conclusion of an OHV impact is supported by the fact that more than 700,000 seedlings were estimated to occur in 2005 in Buttercup Sampling Area 11 alone (Table 4), which would indicate that the species has the potential to produce numbers of adult plants more in concert with the numbers produced in the other management areas of the Dunes.

Seedlings. As Table 4, shows, there were roughly 2.9 million HENIT seedlings in the five sampling areas in which seedling data were collected. Based on this rough estimate it is entirely possible that the total number of HENIT seedlings in all 16 sampling areas may have approached 10 million. This compares to a 2004 Dunes-wide estimate of 1.7 million seedlings (Willoughby 2005b). Because seedling data were collected in only some of the transects in five of the 16 sampling areas, little can be said about any differences in the distribution of the seedling numbers in different areas of the Dunes.

Stage-class composition. Although the number of HENIT seedlings was not estimated across the Dunes, it is obvious from the five sampling areas within which seedling data was taken that seedlings comprised most of the HENIT plants in the Dunes in 2005. Lumping the seedling data together for these five sampling areas and comparing the number of seedlings to the number of adult plants in these five sampling areas, 97.8% of the plants were seedlings. This compares to 85.5% seedlings in 2004 and 90.6% seedlings in 2003. This implies that seedling mortality in this species is high, which would not be unexpected in a relatively long-lived perennial like HENIT, which can produce seed in many years and likely more closely resembles a K-selected species than an r-selected species (Barbour et al. 1987; MacArthur and Wilson 1967; Pianka 1970).

An average of 59.2% of the adult HENIT plants in spring 2005 had flowered were flowering at the time of counting (Table 6). An estimated 192,346 of the dune-wide estimate of 325,122 adults were flowering (Table 5, Figure 10). Maps 4 and 5 show the distribution and abundance of nonflowering and flowering adult plants, respectively.

Table 6 shows the percentages of adult plants flowering at the time of monitoring based on the estimated numbers given in Table 5. As the table shows, the percentage of adult plants flowering ranged from a low of 46% percent for the Buttercup Management Area to a high of 69 percent for the Ogilby Management Area. Some of these differences in percent flowering plants appear to be related to the timing of the monitoring. For example, all but two of the 29 transects read in Sampling Area 11 in the Buttercup Management Area were read in the second week of the study (Table 2), at which time a smaller percent of the plants were in flower than if the transects had been read later in the survey.

Table 6. Percent of 2005 adult HENIT plants flowering at time of monitoring by management area.

Management Area	Percent of Adult Plants Flowering at Time of Monitoring
Mammoth Wash	55.5%
Wilderness	68.1%
Gecko	64.5%
Glamis	55.9%
AMA	52.7%
Ogilby	68.6%
Buttercup	45.4%
Average for Entire Dunes	59.2%

The percentage of adult plants flowering at the time of monitoring was higher in 2005 than in 2004 (dune-wide percentages of 59.2% and 39.7%, respectively). This may be a result of the much drier 2003-2004 growing season. HENIT canopy cover was much greater in 2005 than in 2004, suggesting that the vigor of the species was greater in 2005 (Figure 22).

Differences in density and abundance of adult plants between 2003, 2004, and 2005. As Figure 17 shows, densities of adult HENIT plants did not differ greatly between 2004 and 2005 in any of the management areas or in the Dunes as a whole. There was an estimated 277,955 adult plants in 2004 compared to the 2005 estimate of 325,122, a difference that was not significant (P=0.436). Only the Ogilby Management Area differed significantly in density between 2004 and 2005 (P = 0.015). The density in the Wilderness Management Area differed significantly between 2003 and 2004 (P =0.027). This relative stability in adult population size is what would be expected of a relatively long-lived shrub, particularly since conditions for seedling germination and survival have probably not been conducive for recruitment since the 2000-2001 growing season (see Willoughby 2004 for a discussion of the rainfall distribution and amounts in growing seasons 2000-2001 and 2001-2002 and Table 3 and Figures 1, 2, and 3 of this report for the rainfall distribution and amounts for growing seasons 2003-2003, 2003-2004, and 2004-2005). As stated above, the number of seedlings in 2005 may have approached 10 million. This compares to an estimated 1.7 million seedlings in 2004 (Willoughby 2005b). Furthermore, most of the 2004 seedlings likely germinated in response to February 2004 rains, making their recruitment into the adult population less likely than the 2005 situation, where seedlings likely germinated earlier in the growing season (beginning in October 2004). The 2005 seedlings will therefore have longer to develop before the onslaught of high summer temperatures, possibly enhancing their recruitment into the adult population. Monitoring in

future years should at least partially answer this question, though a demographic study would be far more definitive in this regard.

It is unclear why the two significant differences referenced above (between 2004 and 2005 in the Ogilby Management Area and between 2003 and 2004 in the Wilderness Management Area) would have occurred.

Precision of the estimates. The sampling objective articulated in the ISDRAMP Monitoring/Study Plan is to achieve estimates of Peirson's milk-vetch that are within 30% of the true total population size at the 95% confidence level for each of the management areas. Although this objective was not targeted at HENIT, it was hoped that the level of monitoring required to achieve the objective for Peirson's milk-vetch would achieve similar levels of precision for HENIT. Table 7 shows the precision levels attained for estimates of total population size in each of the management areas and the Dunes as a whole. Table 5 gives precision levels obtained for the other categories for which estimates were made.

Table 7. Precisions attained for 2005 estimates of the total number of adult HENIT plants in each of the management areas and the Dunes as a whole.

Management Area	Precision (+/- percent of the population estimate)
Mammoth Wash	24.9%
Wilderness	29.0%
Gecko	24.2%
Glamis	18.2%
Adaptive Management Area	12.8%
Ogilby	9.2%
Buttercup	27.5%
Entire Dunes	8.3%

As Table 7 shows, the sampling objective for Peirson's milk-vetch was also achieved for HENIT in every management area. HENIT precision levels were far better than those achieved in 2004 (Willoughby 2005b). The improvement from 2004 is a combination of adding four sampling areas and increasing the number of transects sampled. The 8.3% precision for the Dunes-wide estimate is remarkably good.

OHV effects. Figures 11 and 12 display the density and population size, respectively, of adult HENIT plants with signs of damage from OHVs at the time of the survey. Actual numbers are given in Table 5. Map 6 shows the distribution and abundance of these impacted plants. Table 8 shows the percent of the total number of plants that showed signs of impact from OHVs in 2005.

Table 8. Percent of adult HENIT plants showing signs of damage from OHVs in 2005.

Management Area	Percent of Total Number of Plants Impacted
Mammoth Wash	0.3%
Wilderness	0.0%
Gecko	0.7%
Glamis	1.4%
Adaptive Management Area	0.1%
Ogilby	0.2%
Buttercup	13.4%
Entire Dunes	0.6%

Dunes-wide, an estimated 1,935 plants, representing 0.6% of the total estimated adult HENIT plants, showed signs of impact from OHVs. A much higher percentage (13.4%) of the plants in the Buttercup Management Area were impacted by OHVs, which is to be expected because of its proximity to a major camping and staging area, the resulting high OHV use, and its relatively small size compared to the other management areas. The Glamis and Gecko management areas experienced the next highest percentage of plants with OHV damage (1.4% and 0.7%, respectively).

Other damage. Figures 13 and 14 display the density and population size, respectively, of plants damaged by sources other than OHVs. Actual numbers are included in Table 5. Map 7 shows the distribution and abundance of non-OHV damaged plants. Table 9 shows the percent of the total number of plants that showed signs of damage from sources other than OHVs in 2005.

Table 9. Percent of adult HENIT plants with damage from sources other than OHVs in 2005.

Management Area	Percent of Total Number of Plants Damaged
Mammoth Wash	1.1%
Wilderness	2.7%
Gecko	3.6%
Glamis	7.3%
Adaptive Management Area	3.2%
Ogilby	4.3%
Buttercup	3.7%
Entire Dunes	4.1%

Dunes-wide, an estimated 13,373 plants, representing 4.1% of the total estimated adult HENIT plants, showed signs of damage from sources other than OHVs. Most of these damaged plants were infected by sunflower rust, caused by the fungus *Puccinia helianthi*, which attacks both wild and cultivated sunflowers (identification of the pathogen was made by Thomas Gulya, Research Pathologist with the U.S. Department of Agriculture, Agricultural Research Service, Fargo, North Dakota). Although the rust may weaken first year plants to the extent they may not survive the hot, dry summer, older established adult plants probably will survive the defoliation

caused by the rust (Gulya, personal communication). The relatively long-lived rust urediospores are likely always present in the species' habitat, but the rust likely does not appear every year on HENIT because of the infrequent occurrence of rain (Gulya, personal communication). The timing and the amount of rain received in the 2004-2005 growing season was clearly conducive to the growth of the sunflower rust.

The percentage of plants damaged ranged from a low of 1.1% in the Mammoth Wash Management Area to a high of 7.3% for the Glamis Management Area. The reason for this range of percentages is unclear and does not appear to be very closely related to the timing of sampling. It also does not appear to be related to intensity of OHV use (under the assumption that plants impacted by OHV use may be more vulnerable to disease and/or that the rust spores are being spread by OHVs). For one thing, the percentage of plants impacted by OHV use is much lower than the percentage infected by the rust. For another, the percentage of plants infected in the Buttercup Management Area is lower than the Dunes-wide percentage; since the percentage of plants impacted by OHVs is by far the highest in the Buttercup Management Area, one would expect that management area to also have the highest damage from rust infection if OHV use contributed to the infection. As mentioned in the previous paragraph, rust urediospores are likely present throughout HENIT's habitat, awaiting weather conditions conducive to its growth and spread in the HENIT population.

Psammophytic Vegetation

Canopy cover values for all perennial plant species are given in Table 6 for each of the management areas and the Dunes as a whole (because of its large size, cover of the robust annual *Dicoria canescens* is also included in the table, but its cover it not included in the total cover of all perennial plants). There was an estimated 2.3% in total cover (additive cover values for all perennial plants) for the entire dunes. Total cover ranged from a low of 1.1% for the Buttercup Management Area to a high of 3.8% total cover for the Wilderness Management Area (Figure 19). There appeared to be both north-south and west-east gradients in total cover. The Mammoth Wash, Wilderness, and Gecko management areas in the north of the dunes had significantly higher cover than the Adaptive, Ogilby, and Buttercup management areas in the south. The Glamis Management Area had lower cover than the Gecko Management Area to the west. Similarly, the two eastern sampling areas in the Adaptive Management Area had lower cover than the two western sampling areas (Map 9). The Ogilby and Buttercup management areas are exceptions to the west to east trend in decreasing cover: both of their eastern sampling areas had greater cover than their western sampling areas (Map 9). For the Buttercup Management Area this may be the result of relatively heavy concentrated OHV use in its western sampling area; certainly the low cover (0.32%) in that sampling area is at least partially the result of heavy OHV use.

Dunes-wide, total perennial plant cover was significantly greater in 2005 than in 2004 (P=0.000). This is consistent with what would be expected given the much greater and better distributed 2004-2005 growing season precipitation (Table 3, Figures 1-3): greater moisture results in more canopy growth. Except for the Buttercup Management Area, this same trend was observed in every management area, where total perennial canopy cover was greater in every management area in 2005 than in either 2003 (cover was estimated only for the Wilderness and Gecko

management areas in 2003) or 2004 (Figure 20). The Buttercup Management Area had higher estimated canopy cover in 2004, but the difference between 2004 and 2005 was not significant (*P*=0.519). The increase in 2005 cover over that of 2004 was significant in the Mammoth Wash Management Area (*P*=0.008), the Wilderness Management Area (*P*=0.019), The Gecko Management Area (*P*=0.001), the Glamis Management Area (*P*=0.015), and the Adaptive Management Area (*P*=0.010). Only the observed 2004-2005 increase in the Ogilby Management Area was not significant (*P*=0.416).

Eriogonum deserticola (0.86% cover) had the highest cover of any perennial species in the Dunes as a whole, but *Dicoria canescens* (0.85% cover) had essentially the same level of cover (because the latter species is an annual, its cover is not included in the total cover of perennial plants). HENIT (0.47% cover) had the third highest cover of any species on a Dunes-wide basis and *Croton wigginsii* (0.29%) had the fourth highest cover. The cover of these four species by management area is shown in Figures 21-24. As these figures illustrate, the cover of each of these species is not uniformly distributed throughout the seven management areas.

Eriogonum deserticola (Figure 21) had higher cover in the Mammoth Wash and Wilderness management areas than in the rest of the Dunes. It also had generally higher cover in the western portion of the Dunes south of Highway 78 than in the eastern portion. This 2005 cover of this species was generally similar to the 2004 cover and—for the Wilderness and Gecko management areas, the only areas sampled in 2003—to the 2003 cover.

Helianthus niveus ssp. *tephrodes* (Figure 22) had the second highest cover of the perennial plant species in 2005 and the third highest cover when the annual *Dicoria canescens* is factored in. Its pattern of cover distribution is similar to its density pattern (Figure 3), with higher cover values in the northern part of the Dunes than in the southern part. The higher cover values were likely the result of greater stem and leaf growth in 2005 than in 2004 in response to the greater and better distributed rainfall in 2005 as compared to 2004.

Croton wigginsii (Figure 23) had much higher cover values in the Gecko Management Area than in the other management areas. The reason for this difference is not clear.

Dicoria canescens (Figure 24) exhibited a distributional pattern nearly the opposite of that of *Eriogonum deserticola*, in that it showed generally higher cover in the southern and eastern parts of the Dunes than in the northern and western parts. The Adaptive Management Area appears to be an exception to this "rule," however. The reason for lower 2005 cover of the species in the AMA is unclear. The most striking fact about *Dicoria canescens* is the almost complete absence of any cover of this species in 2003 and 2004 (cover was essentially zero for this species in 2003 and 2004 except for a small amount of cover in the Gecko Management Area in 2003). This large annual species puts out a large amount of growth in response to favorable precipitation. It seems clear that the much lower cover in 2003 and 2004 is a result of much lower and more poorly distributed rainfall as compared to 2005.

Summary

In 2005 there were an estimated 325,122 adult HENIT plants throughout the seven management areas of the Dunes. The highest density of HENIT was in the Glamis Management Area and the lowest density was in the Buttercup Management Area. There was something of a north-south gradient in both density and cover of HENIT in 2005, with higher densities and cover values in the northern parts of the Dunes and lower densities and cover values in the southern parts of the Dunes.

The density of adult HENIT did not differ greatly between 2004 and 2005 in either the Dunes as a whole or in any of the management areas except for the Ogilby Management Area which had significantly greater density in 2005 than in 2004. This lack of difference in adult HENIT density between years is not surprising given the apparently long-lived nature of the adult plants and the fact that conditions for recruitment of seedlings into the adult population have probably not been favorable since the 2000-2001 growing season. However, the difference in seedling numbers between 2004 and 2005 was great, with an estimated 1.7 million seedlings in 2004 compared to as many as 10 million seedlings in 2005. Furthermore, the fact that the 2005 cohort likely began germination in October 2004 gives that cohort a better chance of recruitment into the adult population compared to the 2004 cohort which likely germinated in February 2004, giving those seedlings less time to develop prior to the hot summer months. Future monitoring should help answer this question, though not nearly as conclusively as would a demographic study.

The canopy cover of HENIT in the Dunes was greater in 2005 than in 2004 in every management area of the Dunes, likely the result of increased stem and leaf growth in 2005 in response to 2004-2005 growing season rainfall that was greater and better distributed than in the 2003-2004 growing season.

An estimated 0.6% of the total number of estimated adult HENIT plants showed signs of damage from OHVs in 2005, ranging from a low of 0.0% in the Wilderness Management Area to a high of 13.4% in the Buttercup Management Area. The relatively high percentage of plants damaged in the Buttercup Management Area is likely the result of high concentrated OHV use in that management area, which is considerably smaller than the other six management areas and located near a major OHV camping and staging area. The Glamis and Gecko management areas, respectively, experienced the next highest percentage of plants with OHV damage (1.4% and 0.7%, respectively.

An estimated 4.1% of the total number of estimated adult HENIT plants showed signs of damage from sources other than OHVs, primarily from sunflower rust. Damage ranged from a low of 1.1% in the Mammoth Wash Management Area to a high of 7.3% in the Glamis Management Area. The rust damage is not expected to be lethal to most of the adult HENIT plants infected.

Total perennial psammophytic vegetation canopy cover was an estimated 2.3% in total cover over the areas of the dunes that were sampled. Total cover was lowest in the Buttercup Management Area and highest in the Wilderness Management Area. There appeared to be both

north-south and west-east gradients in total cover, with cover higher in the northern and western parts of the Dunes compared to the southern and eastern parts of the Dunes.

Dunes-wide, total perennial plant cover was significantly greater in 2005 than in 2004, consistent with what would be expected given the much greater and better distributed 2004-2005 growing season precipitation. Except for the Buttercup Management Area, this same trend was observed in every management area. *Eriogonum deserticola* had the highest cover of any perennial species in the Dunes as a whole, followed by the perennials *Helianthus niveus* var. *tephrodes* and *Croton wigginsii*. The growing season 2004-2005 was also favorable to the growth of the annual *Dicoria canescens*, which had canopy cover nearly equal to *Eriogonum deserticola* in 2005, but essentially no cover in 2004.

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Appendix 1. Plant Symbols for the Plants Intercepted by the Psammophytic Vegetation Monitoring

Symbol	Scientific Name	Common Name
AMDU2	*Ambrosia dumosa*	burrobush
ASCLE	*Asclepias* sp.	milkweed
ASMAP	*Astragalus magdalenae* var. *peirsonii*	Peirson's milk-vetch
CHLIA	*Chilopsis linearis* ssp. *arcuata*	desert willow
CRWI2	*Croton wigginsii*	Wiggins' croton
DICA4	*Dicoria canescens*	desert twinbugs
EPTR	*Ephedra trifurca*	longleaf jointfir
ERDE9	*Eriogonum deserticola*	Colorado Desert buckwheat
HENIT	*Helianthus niveus* ssp. *tephrodes*	Algodones Dunes sunflower
LATR2	*Larrea tridentata*	creosote bush
PAARG	*Palafoxia arida* var. *gigantea*	giant Spanish needle
PAFL6	*Parkinsonia florida*	blue paloverde
PETHT	*Petalonyx thurberi* ssp. *thurberi*	Thurber's sandpaper plant
PHSO	*Pholisma sonorae*	sand food
PSEM	*Psorothamnus emoryi*	dyebush
TIPL2	*Tiquilia plicata*	fanleaf crinklemat